



Instrument Characterization for Ocean Color Remote Sensing

Gerhard Meister

OBPG (Ocean Biology Processing Group)
NASA Goddard Space Flight Center, Code 616

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My background:

- Phd in 2000, 'BRDF of Urban Areas'
- Joined SIMBIOS in 2000, then OBPG
- SIMBIOS Radiometric Intercomparisons
- MODIS and SeaWiFS calibration and characterization analysis
- VOST: VIIRS prelaunch and on-orbit characterization
- ORCA: instrument design support, PI of Instrument Incubator Program; candidate for PACE mission
- ACE, CLARREO, and HypsIRI: mission definition support
- MERIS Quality Working Group (ESA)
- Instrument development for GeoCAPE
- NASA civil servant since 2010



Overview:

1. Ocean color requirements
2. Sensor requirements
3. Sensor characterization prelaunch
4. Sensor characterization on-orbit



Calibration and Characterization:

Calibration: convert dn to radiance L for ideal conditions

$$L = f(dn)$$

$$L = \text{gain} * dn$$

Characterization: what adjustments need to be made for non-ideal conditions:

$$L = g(P, S, T, \text{etc.}) * f(dn)$$

g can depend on polarization, neighboring bright targets, temperature, etc.



Derivation of ocean color products

Measurement of TOA Radiances
(calibration and characterization)



Conversion to water-leaving radiances
(atm. corr., vic. cal., glint, etc.)

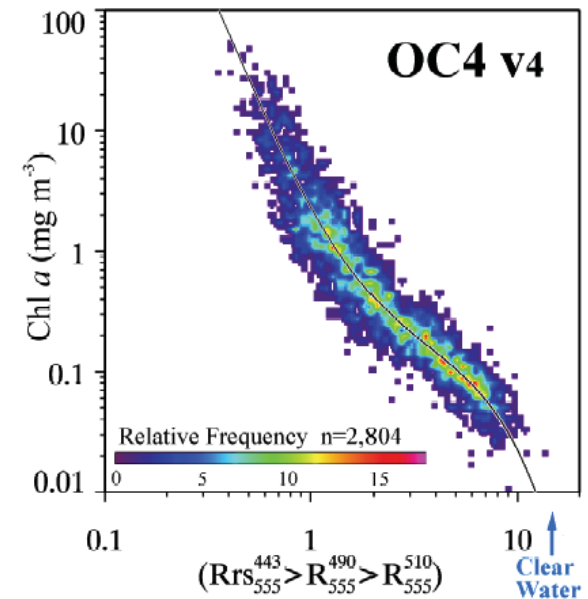
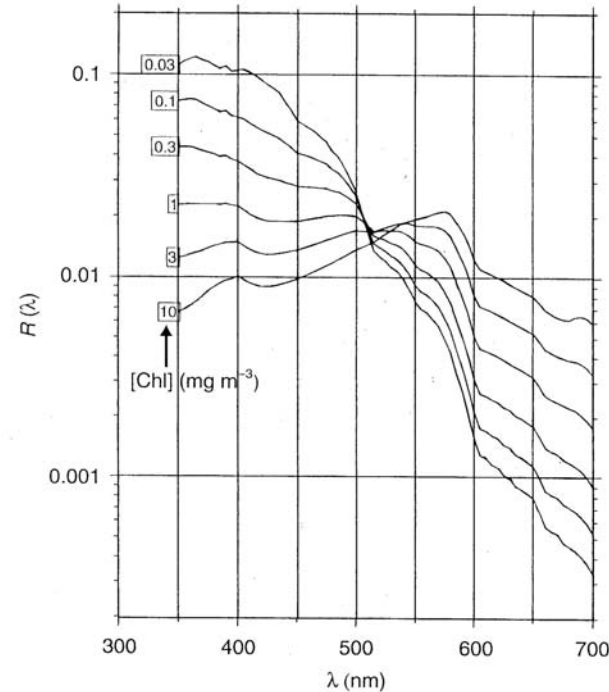


Derivation of ocean color products
(chlorophyll concentration, attenuation
coef., fluorescence line height, etc.)



1. Ocean color requirements

- Basic quantity: normalized water-leaving radiance nL_w
- Some oceanographic variables can be expressed as function of nL_w (chlorophyll concentration, suspended matter, attenuation coef., etc.)



1. Ocean color requirements

- Only 1%-15% of TOA signal is scattered within ocean
- If 5%, then 1% error in TOA signal leads to 20% relative error in nLw

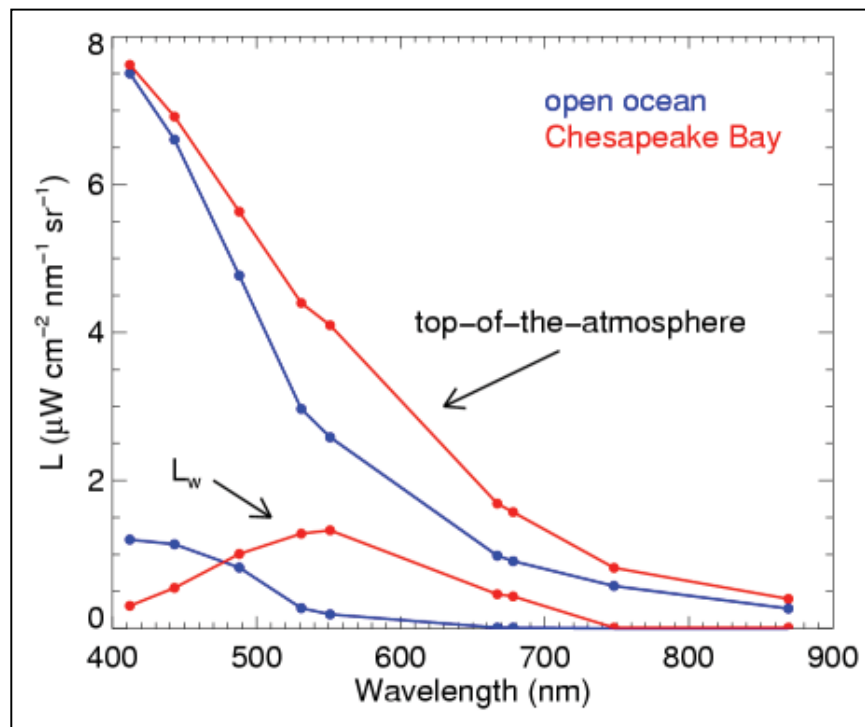


Fig. provided by
B. Franz, OBPG



1. Ocean color requirements

How can we achieve high radiometric accuracy ?

- 1) Design and specifications
- 2) Prelaunch characterization and calibration
- 3) On-orbit monitoring




1. Ocean color requirements

- Historically: 5% goal for nLw at 443nm
- Requires better than 0.5% absolute calibration accuracy, unattainable from space (MODIS: about 2% in reflectance)
- Vicarious calibration (MOBY) adjusts absolute radiance level, so only relative calibration errors are important for ocean color
- Current relative accuracy is about 0.5% or more, goal for future missions probably about half that



2. Sensor requirements

- Ocean color requirements lead to sensor requirements, e.g. ACE Science Traceability Matrix (STM)

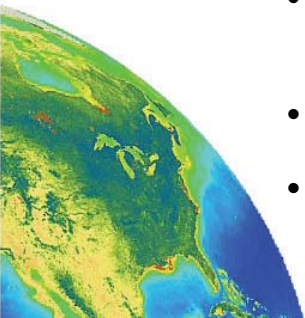
<div>  <div>Ocean Biology STM</div> <div>Goddard Space Flight Center</div> </div>							
Category	Focused Questions*	Approach	Maps to Science Question	Measurement Requirements	Instrument Requirements	Platform Requirements	Other Needs
1 gy	1 What are the standing stocks, composition, & productivity of ocean ecosystems? How and why are they changing? [OBB1]	Quantify phytoplankton biomass, pigments, optical properties, key (functional) phytoplankton groups, and productivity using bio-optical models and chlorophyll fluorescence	1 2 6	Water-leaving radiances in near-ultraviolet, visible, & near-infrared for separation of absorbing & scattering	Ocean Radiometer <ul style="list-style-type: none"> • 5 nm resolution 350 to 755 nm • 1000 – 1500 SNR for 15 nm aggregate bands UV & visible • 1000 SNR for 10 nm fluorescence bands (667, 678, 748 nm band center) 	Orbit permitting 2-day global coverage of ocean radiometer	Global data sets from missions, models, or field observations:
		Measure particulate and dissolved					

- Sensor requirements should be
 - 1) strict enough to ensure quality of data product
 - 2) achievable at reasonable cost
 - 3) testable



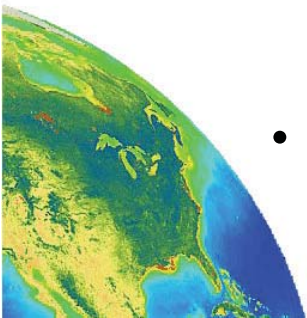
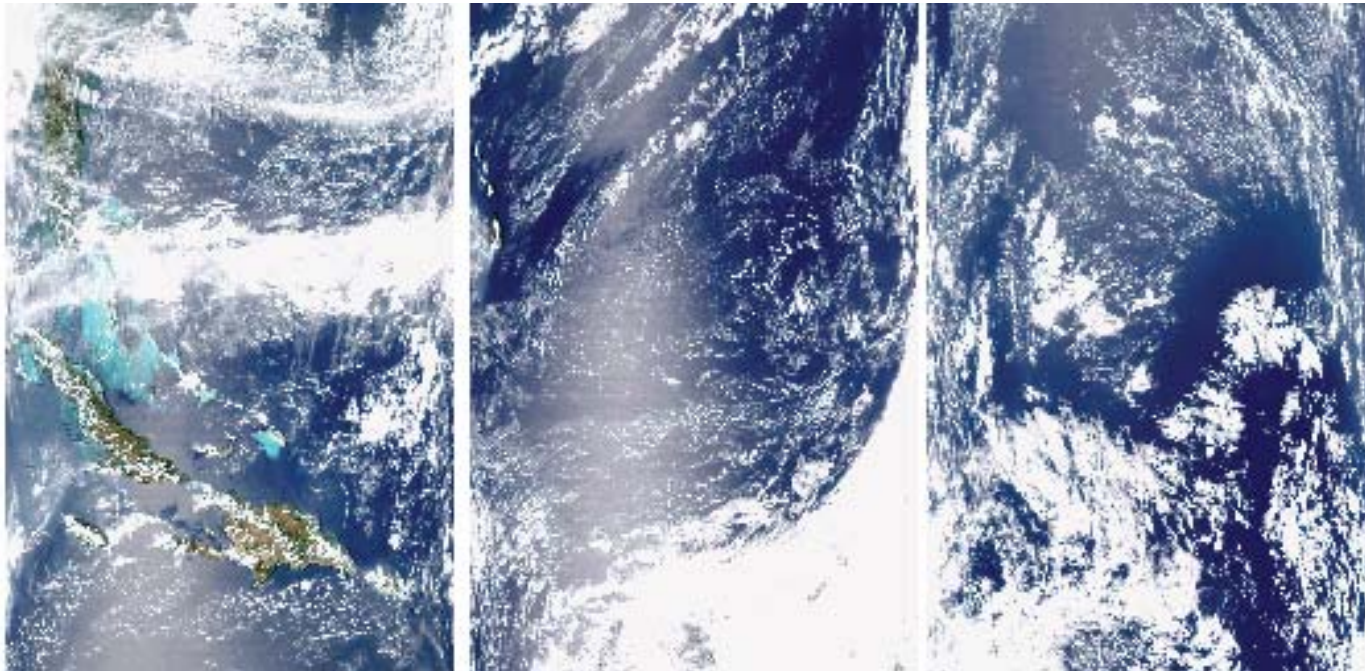
Specific calibration and characterization issues:

- **Polarization** (Meister et al., Applied Optics, 2005 (cover article); Kwiatkowska et al., Applied Optics, 2008; Waluschka et al., SPIE, 2007)
- **Straylight** (Meister et al., SPIE, 2008; Meister et al., ISPRS, 2005; Zhong et al., SPIE, 2007)
- **Gain trending, lunar** (Barnes et al., Applied Optics, 2004; Sun et al., SPIE, 2008; Eplee et al., SPIE, 2008; Patt et al., SPIE, 2005)
- **Gain trending, solar diffuser** (Meister et al., SPIE, 2008; Meister et al., SPIE, 2005)
- **Response versus scan** (Franz et al., JARS, 2008; Kwiatkowska et al., Applied Optics, 2008)
- **Striping** (Meister et al., SPIE, 2007, Meister et al., SPIE, 2006, Xiong et al., SPIE, 2007)
- **Linearity** (Meister et al., SPIE, 2007)
- **Absolute calibration** (Meister et al., Metrologia, 2003; et al.; Meister et al., NASA-TM, 2003, Meister et al., NASA-TM, 2002; Johnson et al., Metrologia, 2003)
- **Temperature** (Eplee et al., SPIE, 2007)
- **Crosstalk, Spectral response, Sensor noise, Field-of-view, etc.**



Sensor requirements not strict enough: VIIRS

- Straylight contaminates high contrast scenes:



- MODIS Aqua: masking 2-3km away from cloud, removes about 50% of the ocean pixels

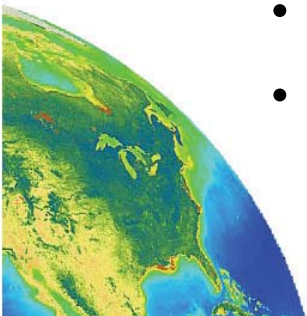
Sensor requirements not strict enough: VIIRS

- VIIRS structured scene (straylight) spec

TABLE 20. Structured Scene requirements

Band	Center Wavelength (nm)	Angular separation from bright target (milliradian)	Maximum allowed ratio of scattered radiance to typical radiance
M1	412	6	0.01
M2	445	6	0.01
M3	488	6	0.01
M4	555	6	0.01
M5	672	12	0.02
M6	746	12	0.02
M7	865	12	0.02

- Cloud size is 12mrad x 12mrad
- 12mrad ~ 10km, 6mrad ~ 5km
- SeaWiFS would pass VIIRS spec in the NIR (SeaWiFS has correction, VIIRS will not; VIIRS straylight performance much better than SeaWiFS, comparable to MODIS)



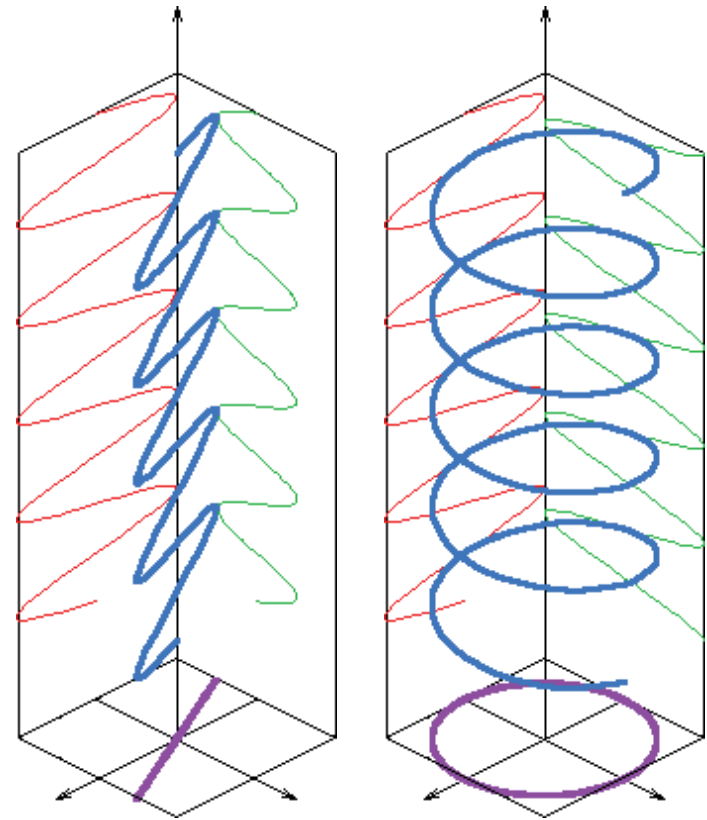
3. Sensor Characterization: Overview

- Polarization:
setup documentation (MODIS and VIIRS)
- MODIS striping:
 - 1) horizontal (detectors)
 - 2) vertical (subframes)



Linear Polarization: Electric Field Vector

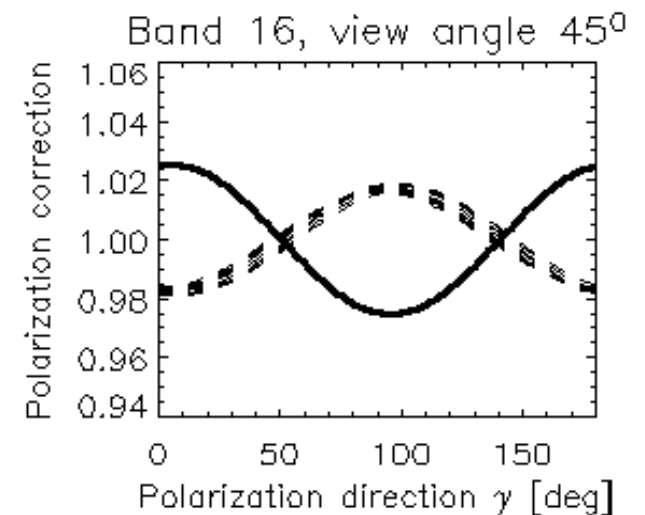
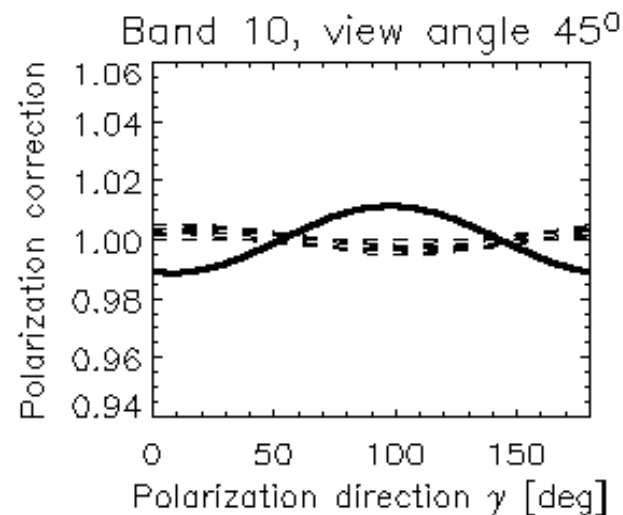
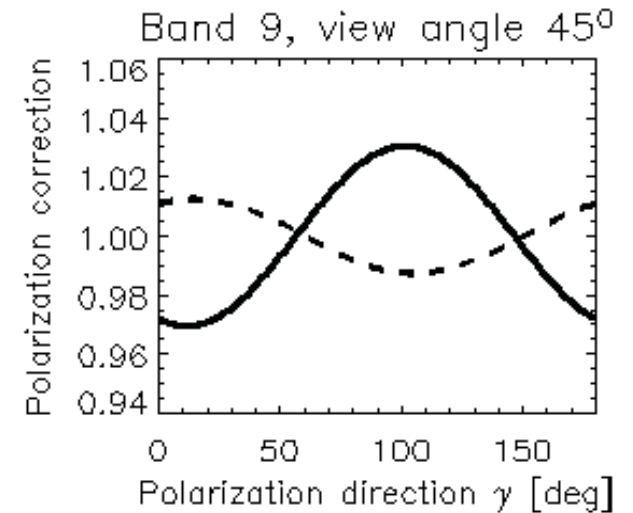
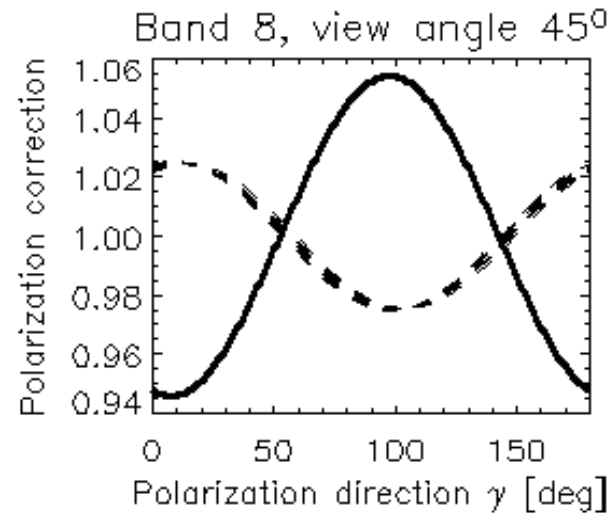
- There are two types of polarization: linear and circular
- TOA radiances are partly (0-70%) linearly polarized
- Prelaunch characterization:
send 100% linearly
polarized into sensor,
varying polarization
angle from 0° - 180°
(15° steps for MODIS
Aqua)



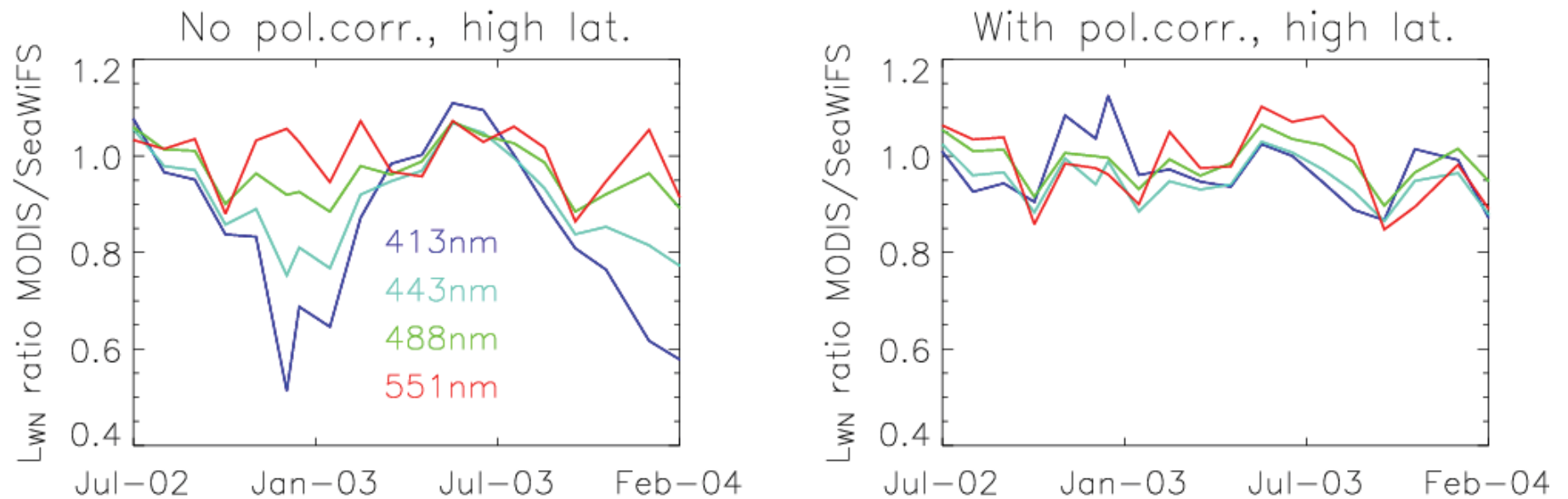
MODIS Polarization Characterization: Setup documentation

Solid line:
Correct
polarization
Correction

Dashed line:
Previous
polarization
correction

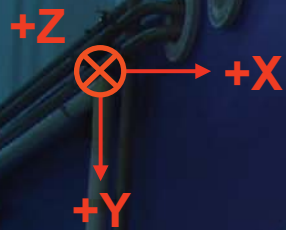


Impact of MODIS Polarization Characterization



nLw ratios MODIS/SeaWiFS for northern pacific






Orientation of the transmitted electric field vector when polarizing sheet is at 0deg:

BVO777: 

BVONIR: 

SIS port 10.5 x 13.8 inches
Polarizer I.D. 11.0 inches
(all scaled to photo incl. FOVs)

VIIRS flight direction: 

VIIRS scan direction: 

(VIIRS scans from -55deg to +55deg view angle)

Polarizing sheet rotation angles:



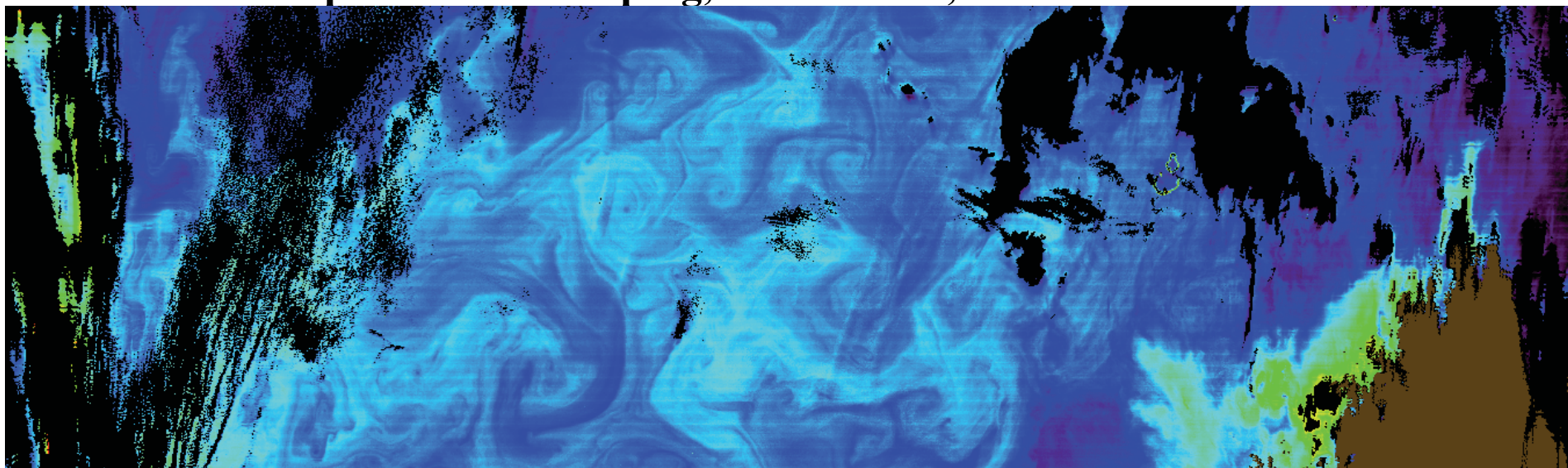
FOV of VIIRS detector 16 (instrument engineering order)

FOV of VIIRS detector 1 (instrument engineering order)

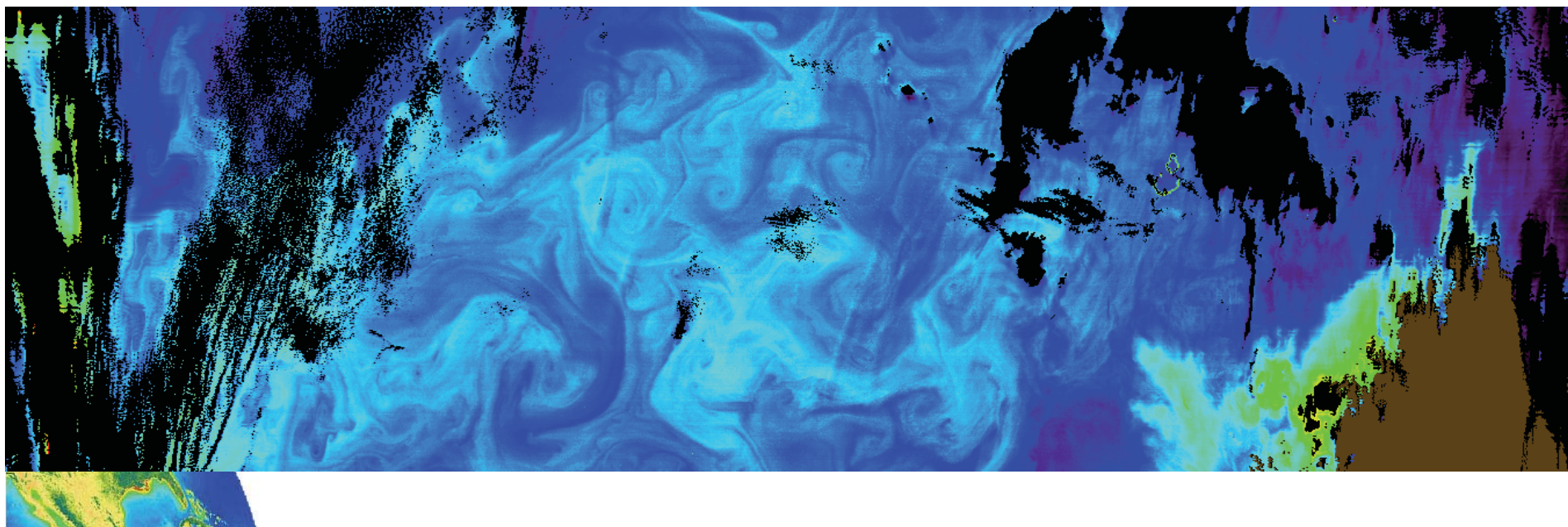
FOVs are 7.39 x 6.82 inches



MODIS Aqua detector striping, nLw 412nm, before correction:



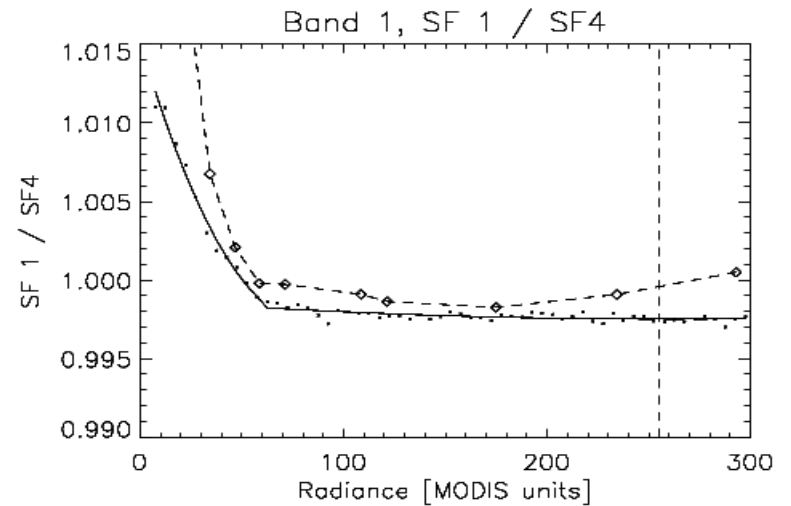
After correction:



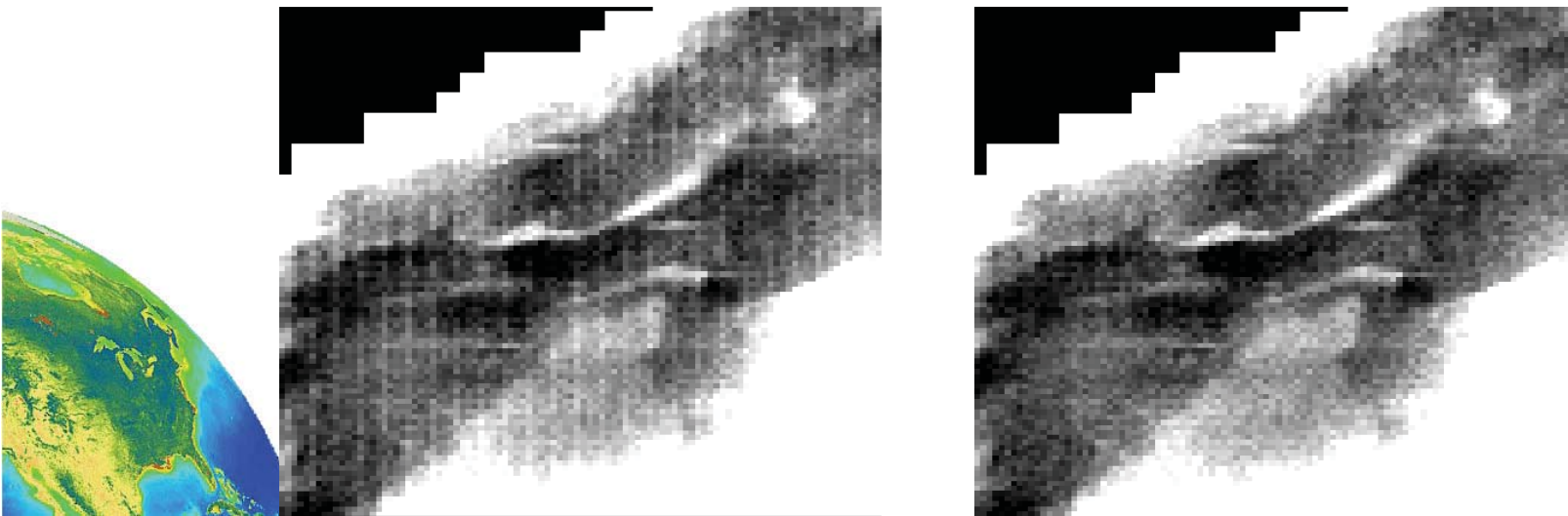
MODIS subframe striping correction

- Subframes not linear versus radiance, prelaunch and on-orbit:

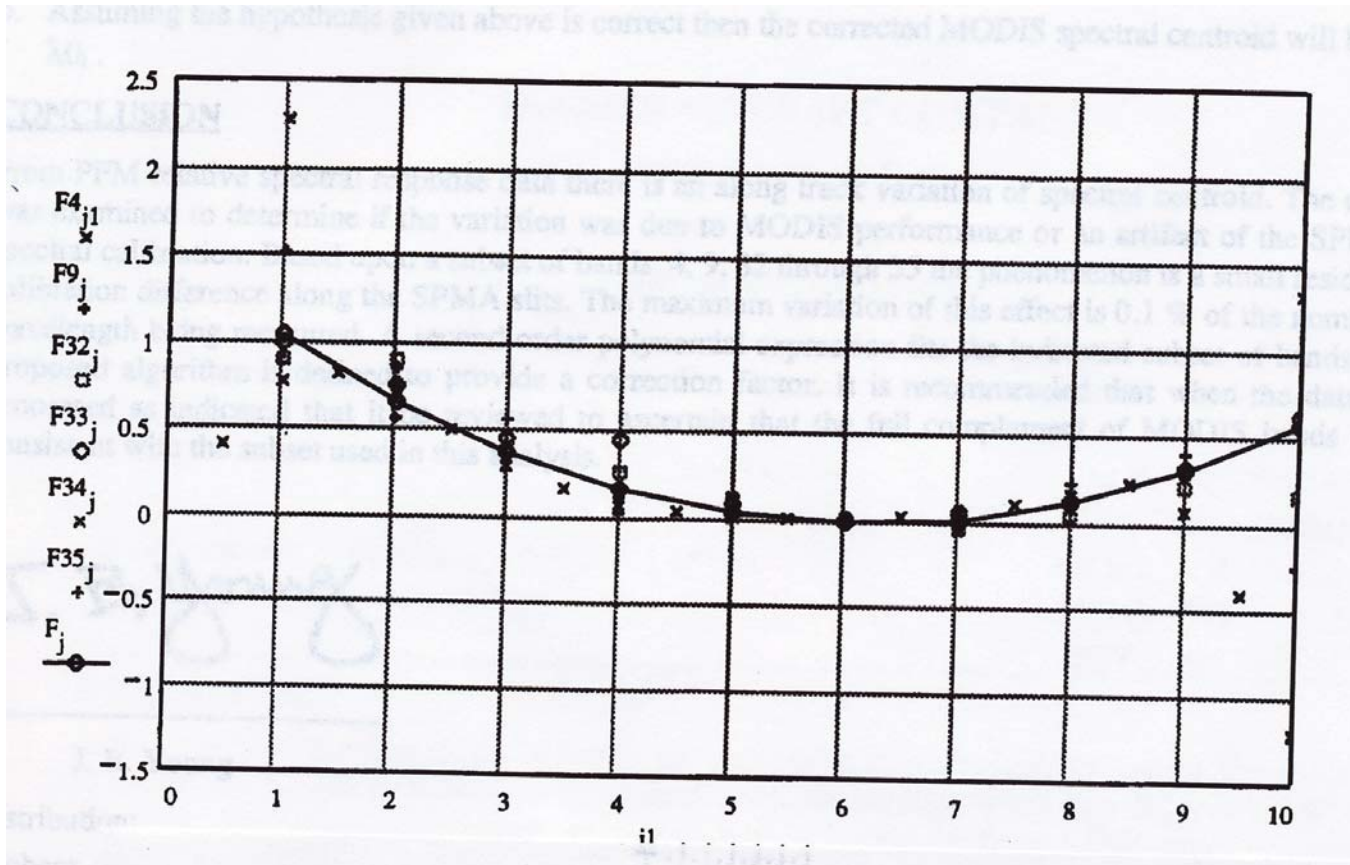
Figures from Meister et al., SPIE, 2007



- nLw 645nm (before/after correction):



MODIS Relative Spectral Response:



- Issues: detector dependence (real and smile correction), source intensity (low and not well known)



4. Sensor calibration on-orbit

- Problem: how to calibrate sensor several hundred miles away ?
- Solution 1: carry calibration sources (solar diffuser, blackbody, spectral targets)
- Solution 2: use natural sources (moon, deserts, clouds, atmospheric absorption lines)



Sensor calibration: SeaWiFS

- SeaWiFS optics based on a telescope design, with well protected half-angle mirror
- SeaWiFS optics + detectors have degraded consistently => one analytical function sufficient to model sensor degradation
- Error of individual lunar measurements ($\sim 1\%$) does not affect calibration accuracy of SeaWiFS

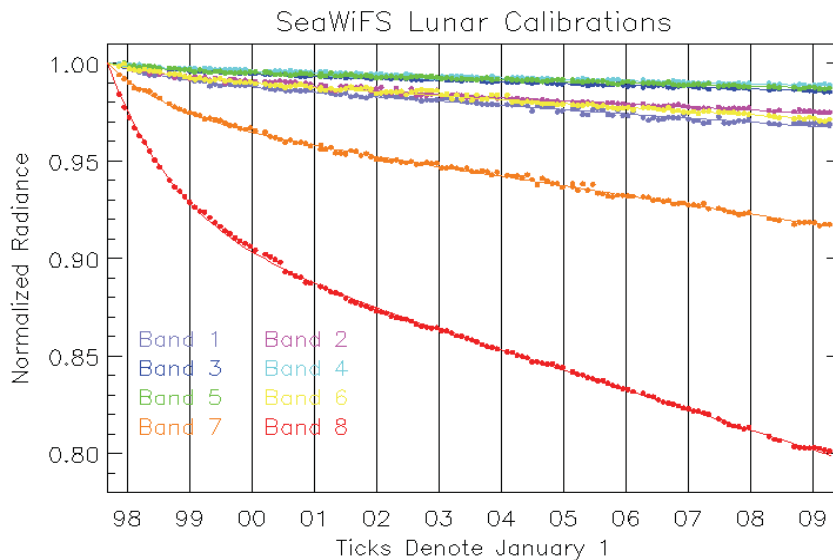


Fig. created
by G. Eplee,
OBPG

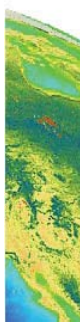
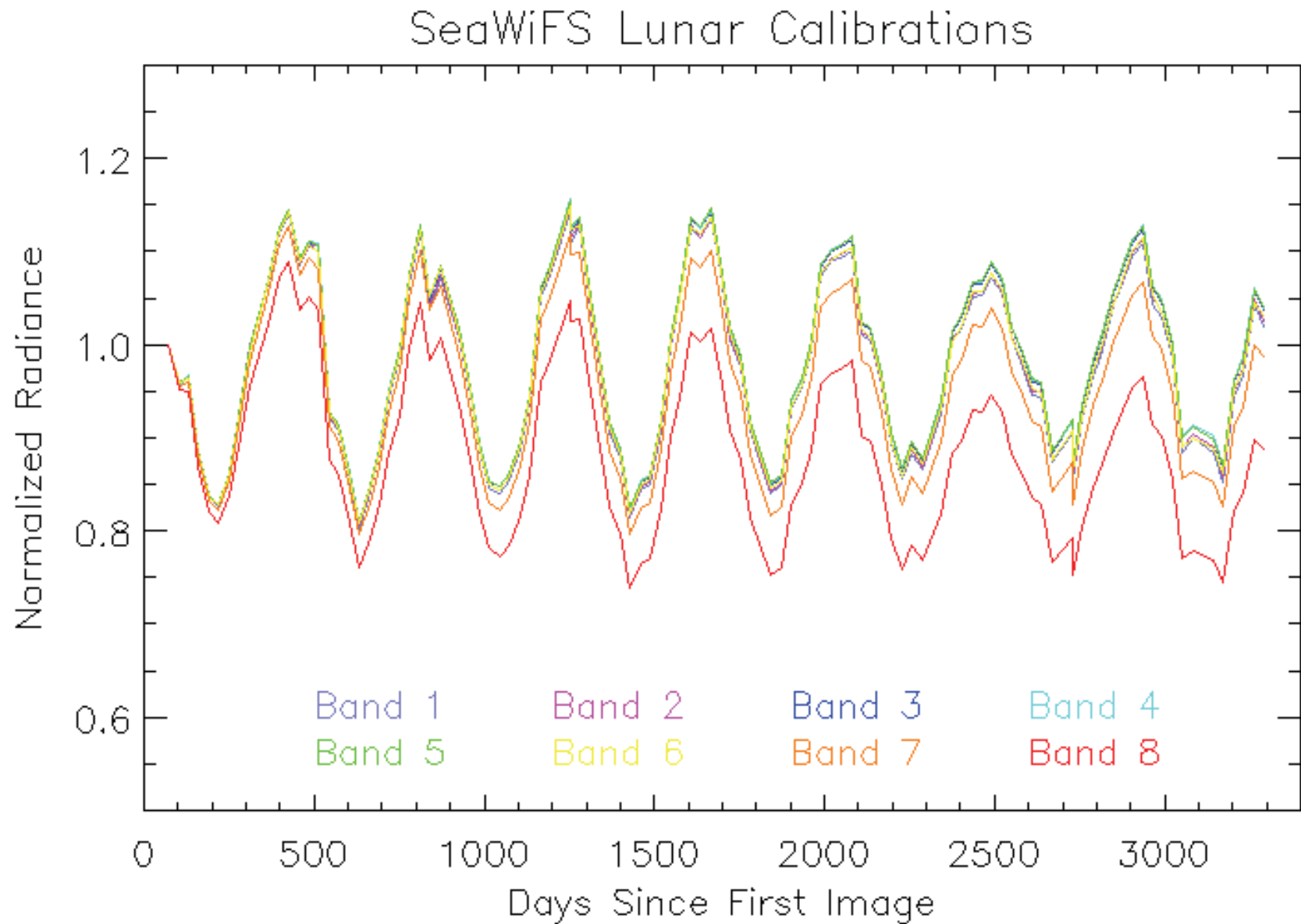


SeaWiFS Lunar Image



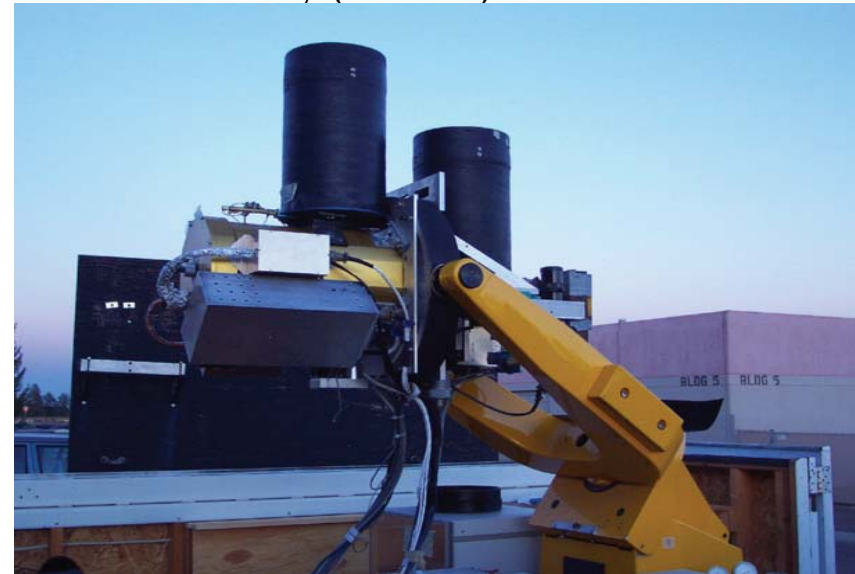
First step: Sum all
lunar pixels (radiance
to irradiance)

Monthly SeaWiFS lunar irradiance measurements



Lunar Calibration

- Application to space-based instruments requires using a photometric model
 - to accommodate unrestricted observation (illumination and view) geometry
- Currently, the radiometric quantity utilized is spatially-integrated irradiance
 - improved signal-to-noise through summation of pixels
 - enhanced freedom in model development
- USGS lunar irradiance model was built from database of spatially resolved images of the Moon acquired by the RObotic Lunar Observatory (ROLO)
 - 6+ years in operation, >85,000 individual Moon images (many $\times 10^5$ star images)
 - twin telescopes, 32 wavelength bands, 350–2450 nm



USGS campus
Flagstaff, AZ



Using the Moon — Lunar Irradiance Model

- described in: H.H. Kieffer and T.C. Stone “*The Spectral Irradiance of the Moon*”, *Astronomical Journal* 129, 2887-2901 (2005 June)
- empirically-derived analytic function in the geometric variables of phase and libration, for disk-equivalent reflectance

A:

$$\ln A_k = \sum_{i=0}^3 a_{ik} g^i + \sum_{j=1}^3 b_{jk} \Phi^{2j-1} + c_1 \theta + c_2 \phi + c_3 \Phi \theta + c_4 \Phi \phi \\ + d_{1k} e^{-g/p_1} + d_{2k} e^{-g/p_2} + d_{3k} \cos((g - p_3)/p_4)$$

g = phase angle

θ = observer selenographic latitude

ϕ = observer selenographic longitude

Φ = selenographic longitude of the Sun



Example of ROLO input file: Sirad

SECTION = Observation Info

Instrument = SeaWiFS

User = Gene Eplee

Process = multimoon

Version = 2002apr03

Run_Time = 2005Jan05 14:00:00

BEGIN_FREE

This is ROLO exchange SCT MOF Irradiance file.

Prelaunch calibration with best time correction applied.

The irradiances are integrated over pixels above 1% of maximum.

Col_0 = Obs_index Col_1+ = Irradiance in bands

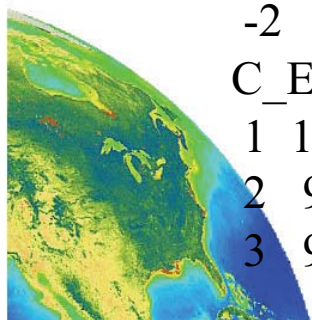
Units are: $\mu\text{W} / \text{m}^2 / \text{nm}$

Format = (i2,8f8.4)

-1	1	2	3	4	5	6	7	8
-2	412.	443.	490.	510.	555.	670.	765.	865.

C_END

1	10.23306	12.39135	14.35401	14.27165	15.17209	14.61134	12.98814	10.44421
2	9.78679	11.85517	13.73272	13.66103	14.54734	14.01934	12.44731	10.01145
3	9.91586	12.00497	13.88532	13.80062	14.66388	14.08408	12.49814	10.04028



Example of ROLO input file: Sgeom

SECTION = Observation Info

Instrument = SeaWiFS

User = Gene Eplee

Process = multimoon

Version = 2002apr03

Run_Time = 2005Jan05 14:00:00

BEGIN_FREE

 This is ROLO exchange SCT MOF Geometry file.

 The Moon_Y_Size is defined by the 1% of maximum pixels.

Col_0 = Obs_index Col_1 = Image_time Col_2,3,4 = Spacecraft_X,Y,Z

Col_6 = Moon_Y_Size <mrads> [Col_7=Miss_Frac Col_8=Clip_angle]

Format = (i2,a19,3f7.1,f6.3,f7.4,f4.1)

C_END

1	1997-11-14T22:50:09	4122.0	5570.3	1480.1	31.931	0.0000	0.0
2	1997-12-14T12:18:26	945.1	6757.2	1912.9	31.517	0.0000	0.0
3	1998-01-13T01:44:52	-2527.0	6418.3	1631.4	30.775	0.0000	0.0



Example of ROLO output file: Lgeom

SECTION = Observation info ! ----- Begin a section
 Instrument = SeaWiFS ! Instrument making the observation
 User = Gene Eplee ! Person submitting the calibration request
 Source_Date = 2005Jan05 14:00:00 ! Run Date/Time of primary input file
 Process = 2004jun24T12:14 & multimoon ! Name of process that generated this file
 Version = 2005jul24 ! Processing version
 Run_Time = 2006Mar21 08:52:49 ! Local Date/Time of these calculations
 BEGIN_FREE ! Begins a free-form section describing the table section
 This is a ROLO exchange for: LCT MOF geometry

GUIDE to columns below:

Col Key units Description

0 Row - Observation Count

1 TDB-2451545 day Dynamical barycentric Days -2451545.

2 SunLon degree Selenographic longitude of the Sun

3 SunLat degree Selenographic latitude of the Sun

4 SC_Lon degree Selenographic longitude of spacecraft

5 SC_Lat degree Selenographic latitude of spacecraft

6 SC_Dist. km Distance of spacecraft from center of Moon

7 Sun_M_Dist AU Heliocentric range of the Moon

8 DistFac - Factor to correct irradiance to standard distances

9 PhaseAng degree Signed phase angle

10 Moon_mrad mrad Angular Diameter of the Moon from SC

11 Axis_Ang degree Position Angle of lunar axis, ccw from N

Format = (I3,1x,f13.6,1x,f8.2,1x,f5.2,1x,f6.2,1x,f6.2,1x,f8.1,1x,F9.7,1x,f9.6,1x,F8.3,1x,f8.4,1x,f8.3)

Row TDB-2451545 SunLon SunLat SC_Lon SC_Lat SC_Dist. Sun_M_Dist DistFac PhaseAng Moon_mrad Axis_Ang

C_END End of label section

1 -777.547791 -0.40 1.42 4.46 6.16 361263.7 0.9915820 0.868439 6.780 9.6185 -13.242

2 -747.986450 0.03 1.53 5.27 6.31 371926.9 0.9867886 0.911584 7.085 9.3427 -0.551

3 -718.426453 0.64 1.18 4.93 4.61 383036.8 0.9860848 0.965479 5.485 9.0717 11.964



Example of ROLO output file: Lirad

SECTION = Observation info ! ----- Begin a section
Instrument = SeaWiFS ! Instrument making the observation
User = Gene Eplee ! Person submitting the calibration request
Process = 2004jun24T12:14 & multimoon ! Name of process that generated this file
Version = 2005jul24 ! Processing version
Run_Time = 2006Mar21 08:52:49 ! Local Date/Time of these calculations
Lunar_model = 311g = [coeff=r311g adjust=r311g05]

!! Corrections:

BEGIN_FREE ! Begins a free-form section describing the table section

This is a ROLO exchange for: LCT MOF Irradiance

See matching Geometry file for comments

GUIDE to columns below:

Headers: Row-1=band

Row-2=Nominal wavelength

Row-3=Effective wavelength for the Moon

Table : Col_0=count Col_1=oversample factor. Remaining columns are
% disagreement, with a row for each observation

(Spacecraft_Irradiance/ROLO_Irradiance -1.) in percent.

Format = (i3,f8.4,12f8.3)

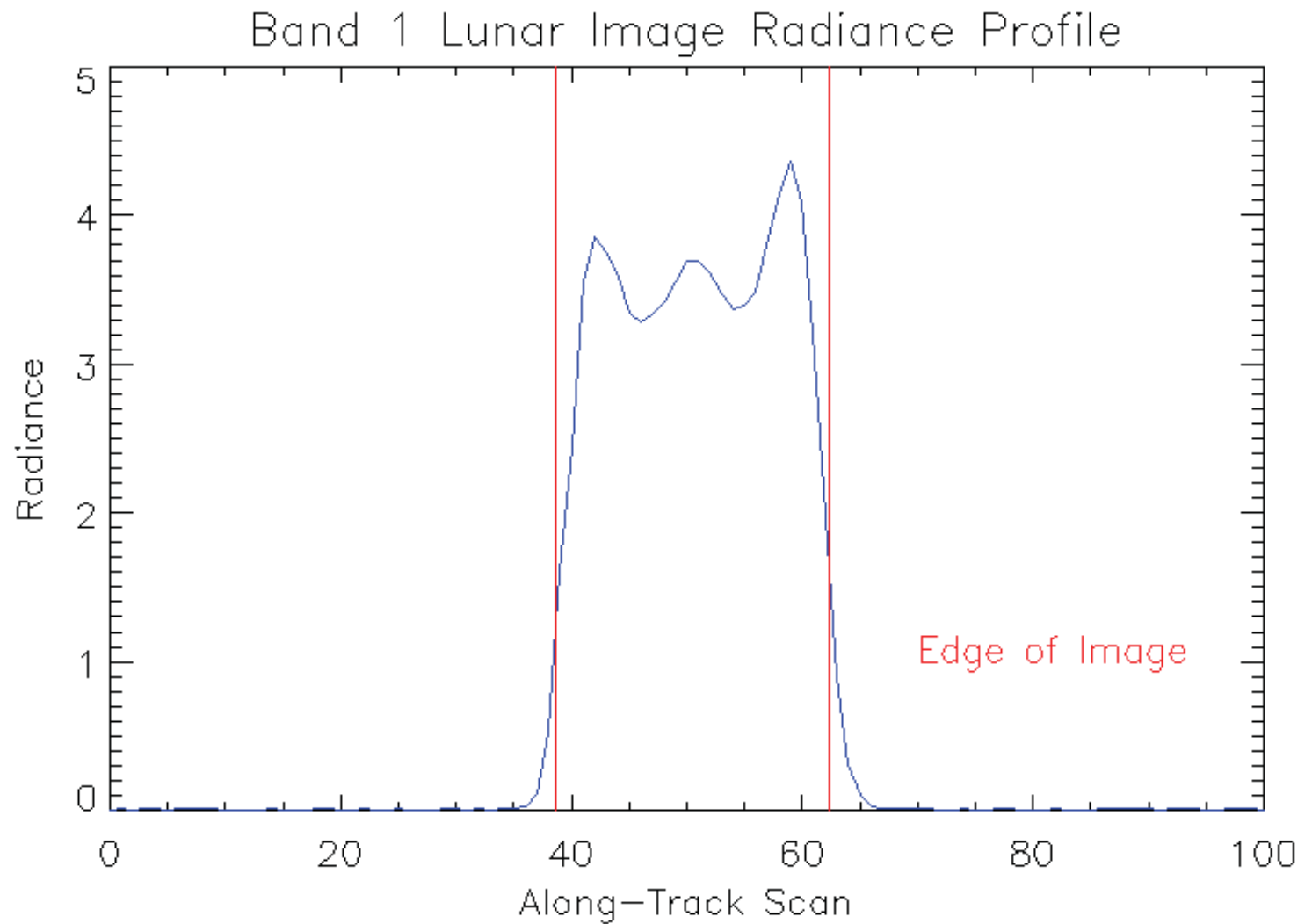
-1	1	2	3	4	5	6	7	8
-2	412.	443.	490.	510.	555.	670.	765.	865.
-3	414.50	444.71	491.91	510.20	556.40	668.37	766.85	863.61

C_END End of label section

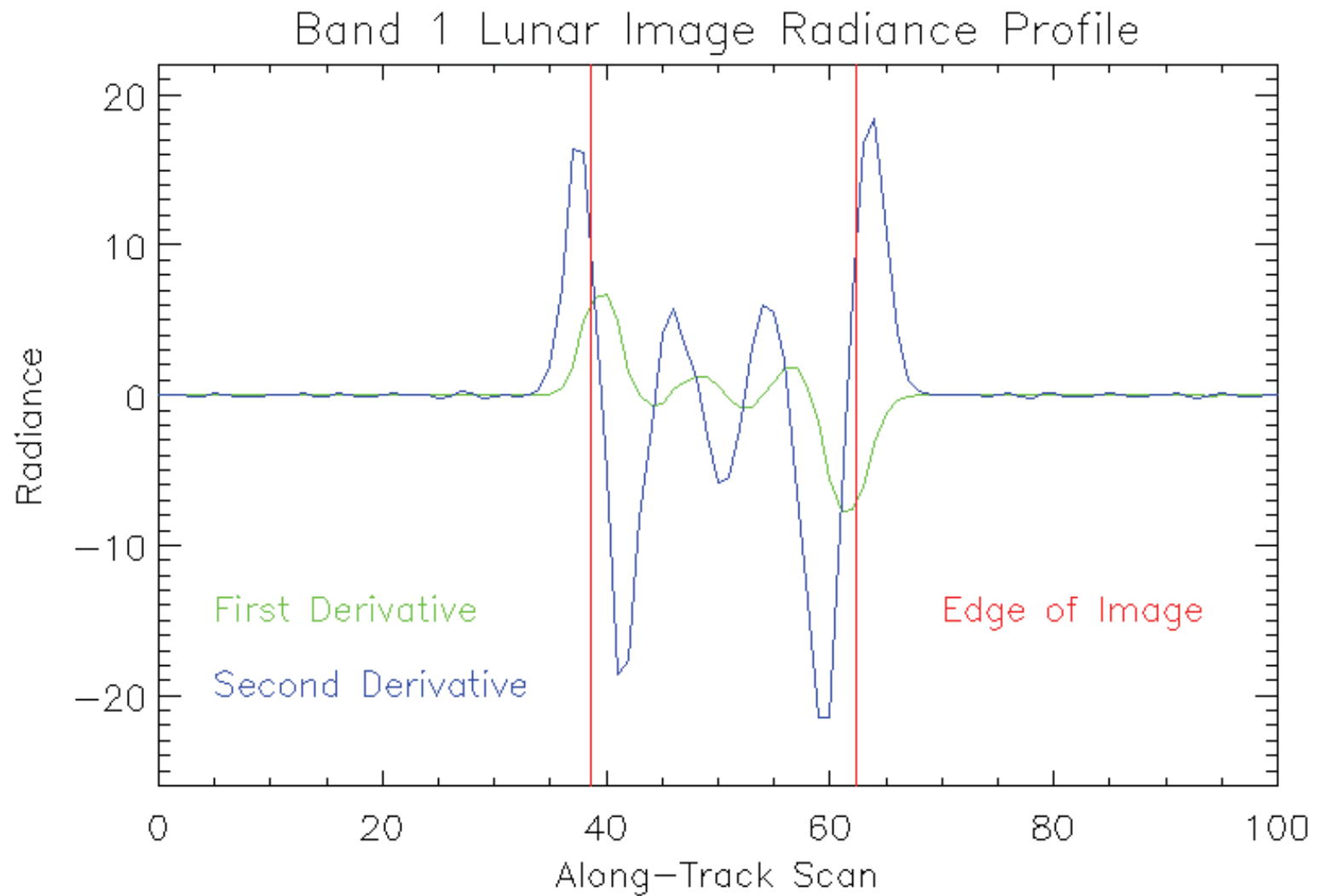
1	3.3198	0.006	1.245	4.170	3.263	4.037	5.621	8.087	4.590
2	3.3734	0.047	1.290	4.180	3.314	4.239	5.835	8.138	4.649
3	3.3924	-0.991	0.331	3.235	2.353	3.158	4.714	7.136	3.635



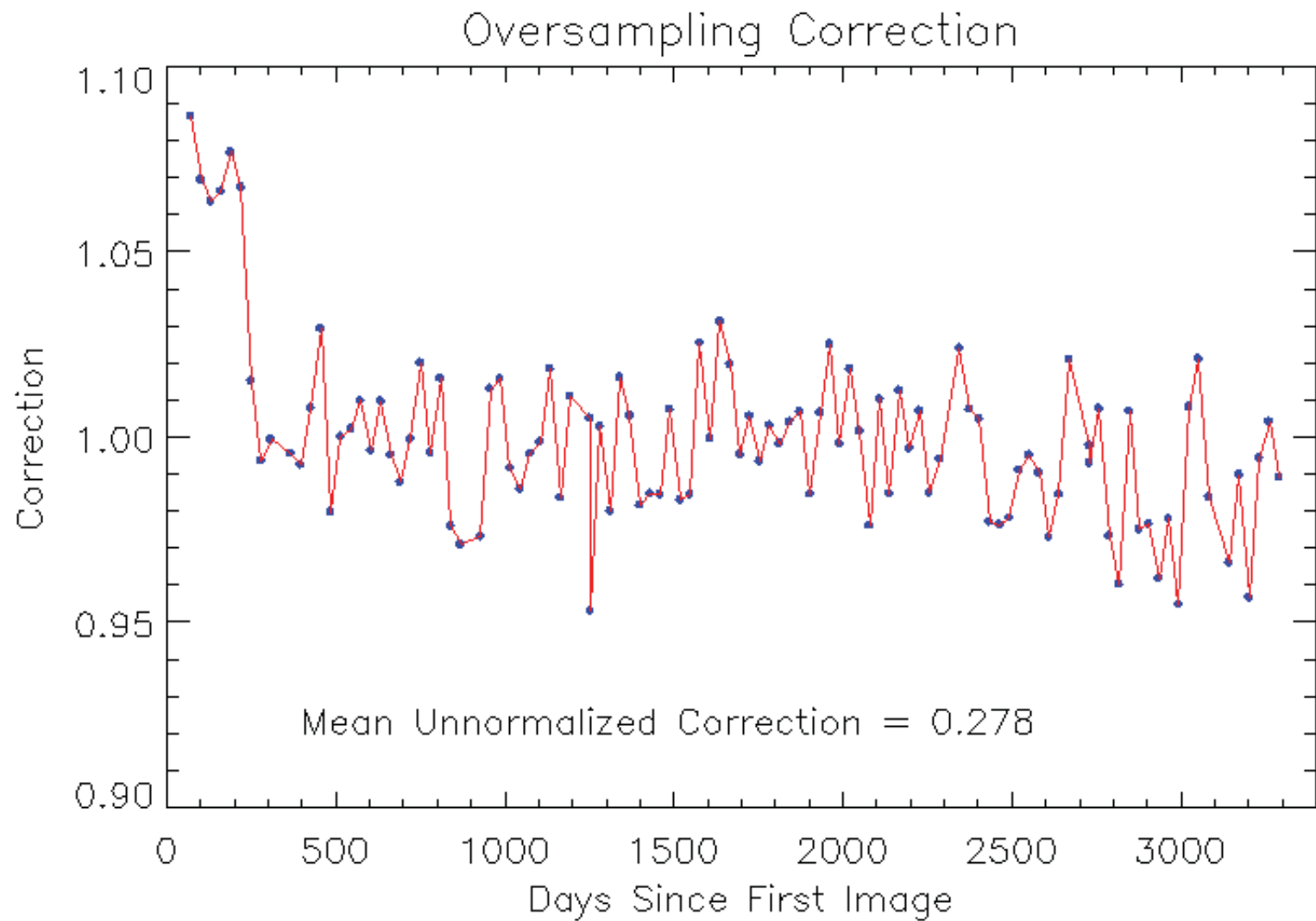
How to determine the apparent size of the moon:



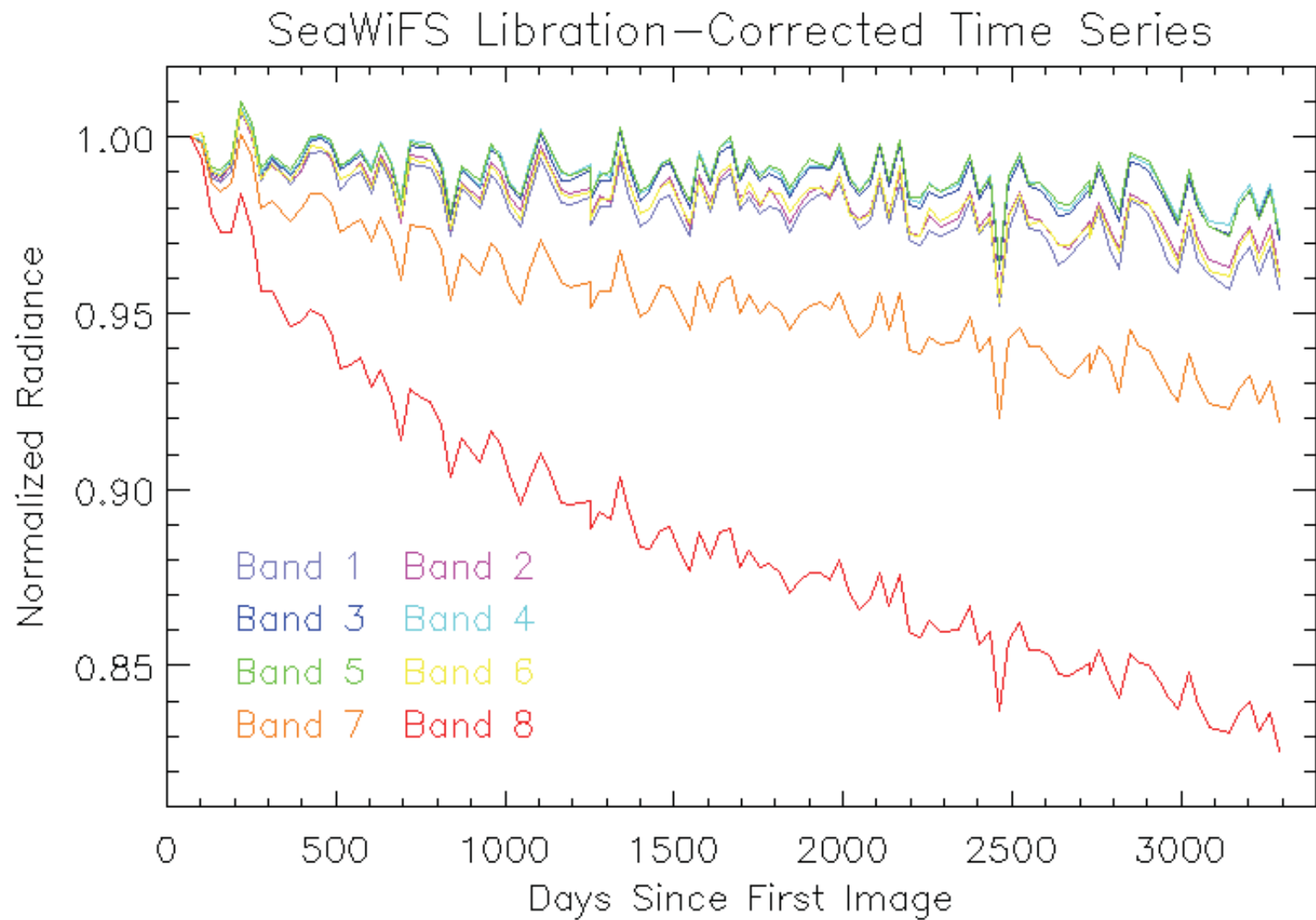
How to determine the apparent size of the moon:



Apparent size of the moon as a function of time:



Lunar irradiances after ROLO and oversampling correction:



SeaWiFS temperature correction

- SeaWiFS band 8 calibration temperature dependence on-orbit differs from prelaunch measurements
- Successfully corrected using lunar data
- Prelaunch Tvac different from on-orbit temperature environment
- Additional change since 2005 could be related to SeaWiFS orbit drift

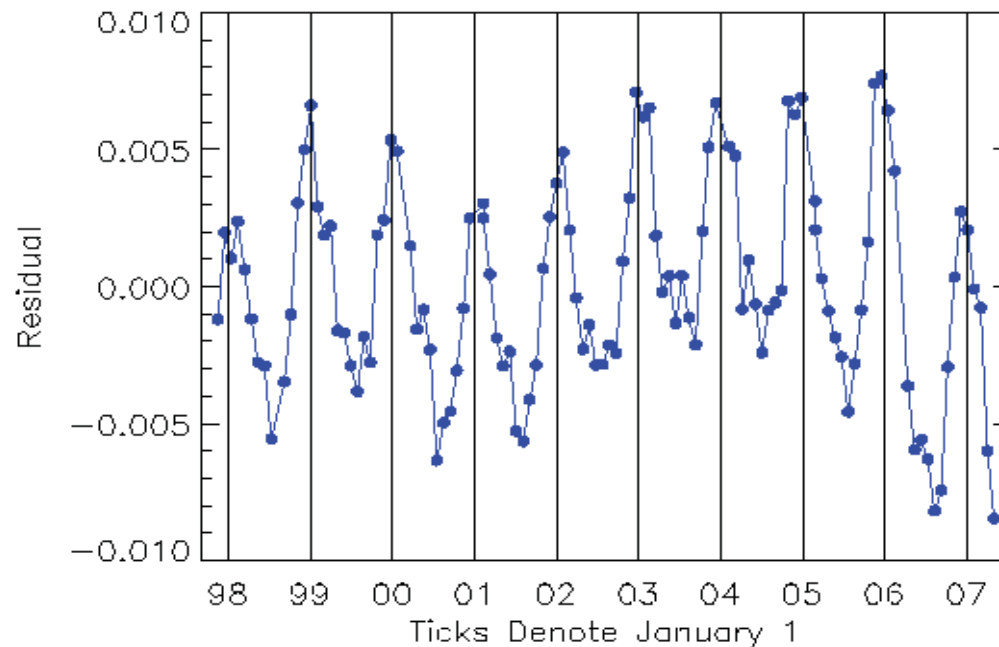
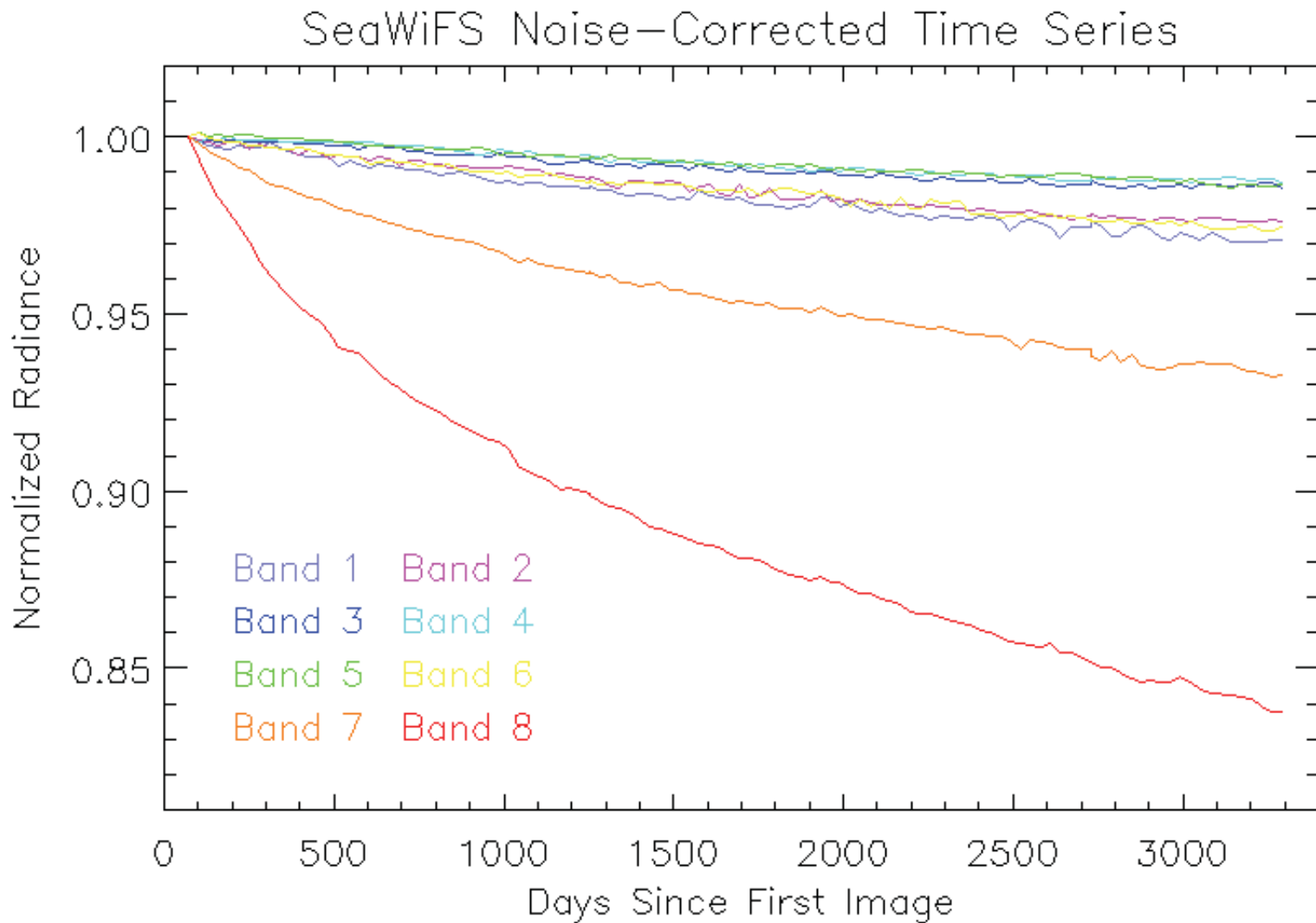


Fig. from
Eplee et al.,
SPIE, 2007



Lunar irradiances after noise correction:



VIIRS On-Orbit Calibration:

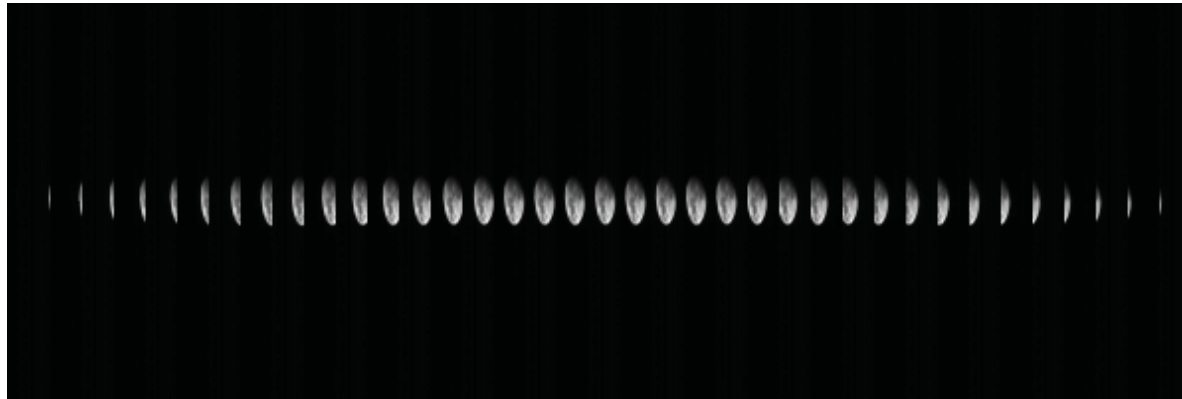
Lunar Time Series
Solar Time Series
Comparison



Slides provided by G. Eplee, SAIC



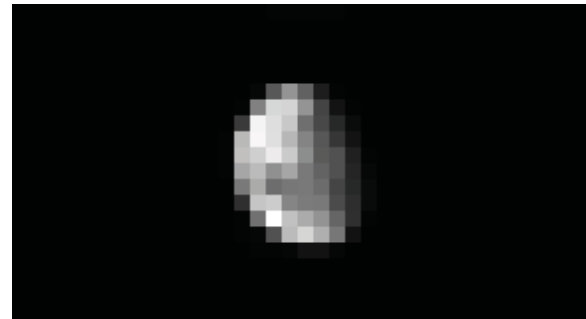
Lunar Calibration Data



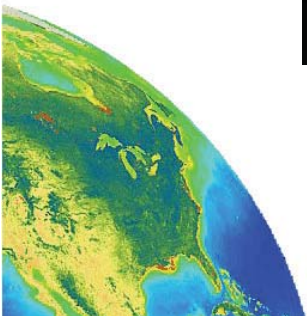
M4 Lunar Calibration Image Sequence



M4 Lunar Image
Unaggregated



M6 Lunar Image
Aggregated



Lunar Calibrations

Cal Date	Cal Type	Bands	Gains	Phase
Jan 4	Roll	M3-M7	High, Low	-55.4
Jan 5	Serendipitous	M1-M3	High, Low	-44.5
Feb 3	Roll	M6,M8-M11	High, Low	-56.2
Feb 3	Roll	M1-M5,M7	High, Low	-55.4
Mar 4	Serendipitous	M3,M5-M11	High, Low	-48.9
Apr 2	Roll/Sector Rot	M1-M11	High	-51.2
May 2	Roll/Sector Rot	M1-M11	High	-50.9
May 31	Roll/Sector Rot	M1-M11	High	-53.0
Jun 28	Serendipitous	M8, M9, M11	High, Low	-66.7
Jun 28	Serendipitous	M5-M7,M10	High , Low	-65.7
Jun 29	Serendipitous	M1-M4	High, Low	-64.8
Oct 25	Roll/Sector Rot	M1-M11	High	-51.0
Nov 23	Roll/Sector Rot	M1-M11	High	-50.7



Lunar Data Analysis

Analysis methodology:

- Calibrate lunar radiances, compute disk-integrated lunar radiances
- Use IFOV to convert radiances to irradiances: rectangular pixels
- Band aggregation is accounted for by oversampling correction
- ROLO Model is used to compute lunar residual time series

Observations:

- Radiometric response degradation is strongest in the red (Bands M5-M7)
- Degradation in blue (Band M1) from “yellowing” of optics is observed

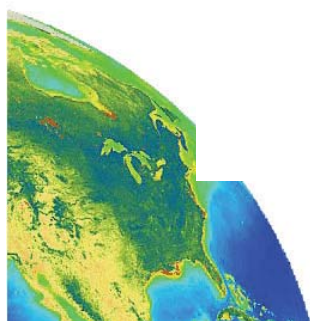
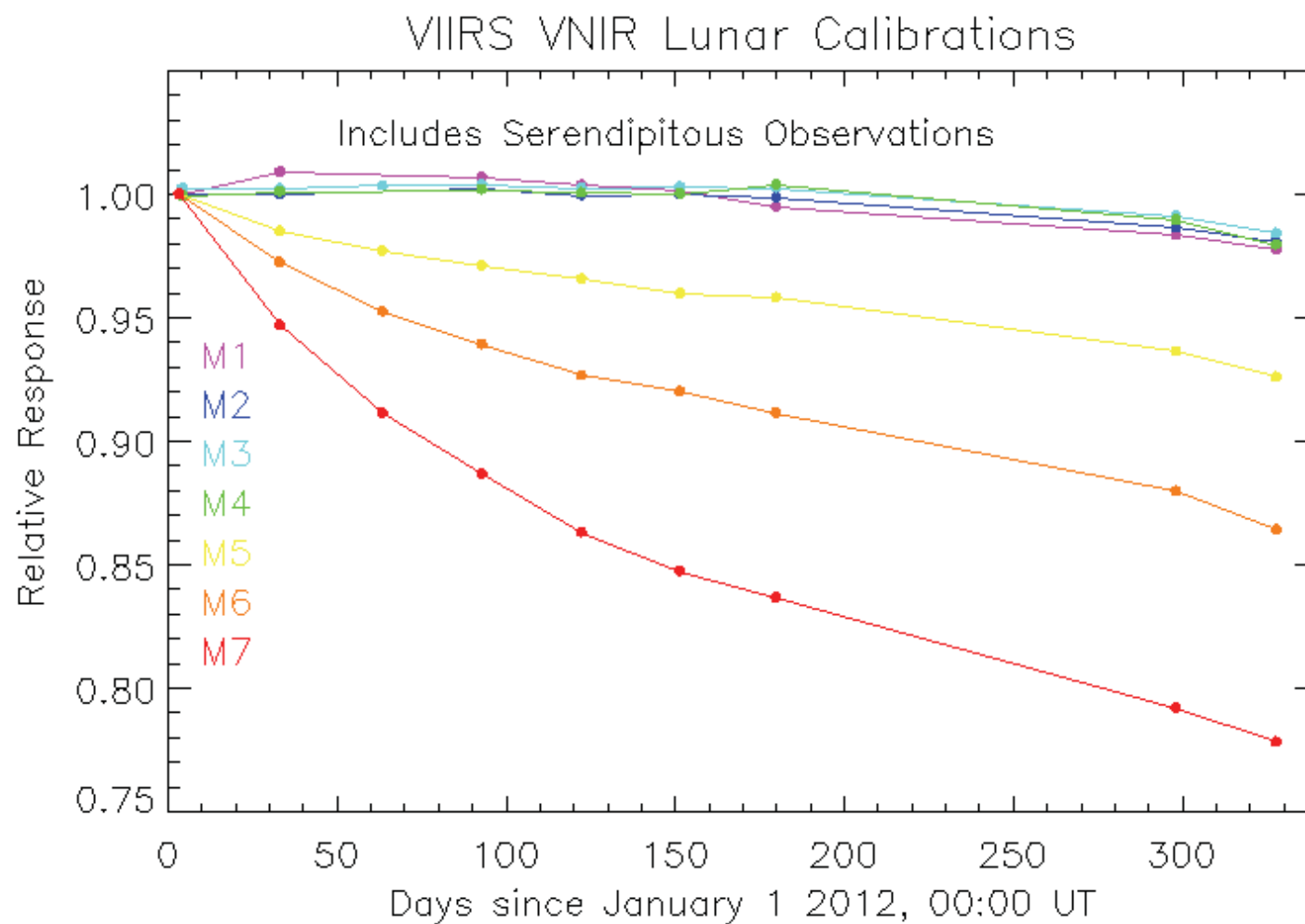
Concerns:

- Limited amount of low-gain calibration data
- Is observational noise low enough to allow a detector-specific calibration?

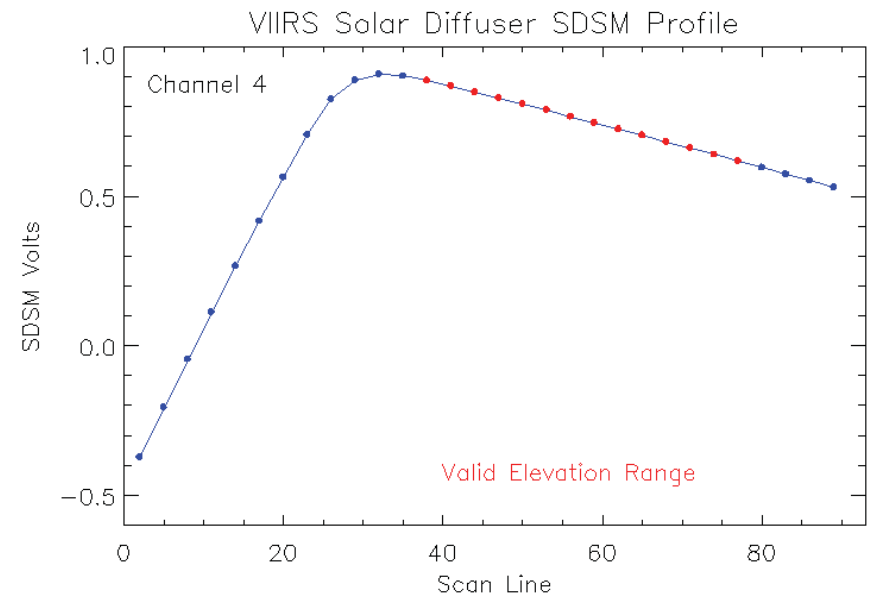
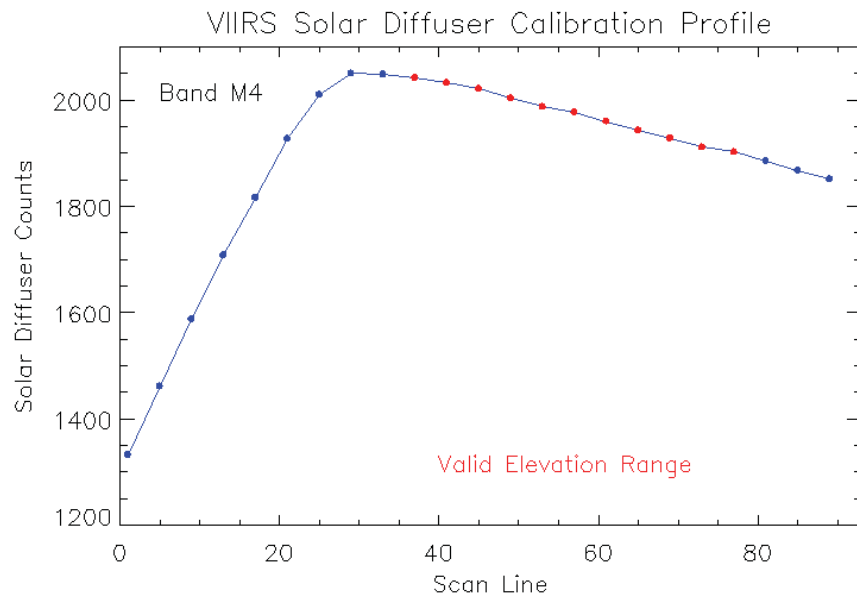
The following plots show the High Gain, Mirror Side 0 data.



Lunar Time Series



Solar Calibration Data



Solar diffuser provides spatially homogeneous light,
opposite of lunar image



Solar Diffuser Data Analysis

Analysis methodology:

- F-factor time series starting on January 2 are used for calibration
- SDSM-derived BRDF corrections are applied to F-factors
- Corrected F-factors are smoothed, then interpolated to a daily time basis
- Striping corrections are applied to corrected F-factors
- F-factors are interpolated between daily LUT entries in Ocean PEATE code

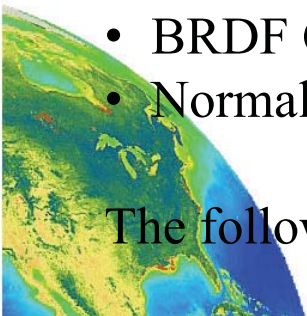
Observations:

- Radiometric response degradation is strongest in the red, ~zero in the blue
- Size of uncorrected F-factors for bands M1-M3 is ~ size of BRDF corrections

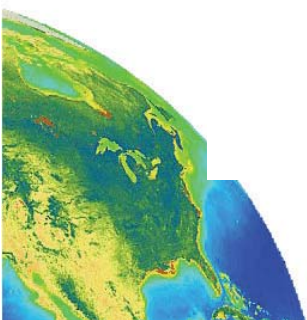
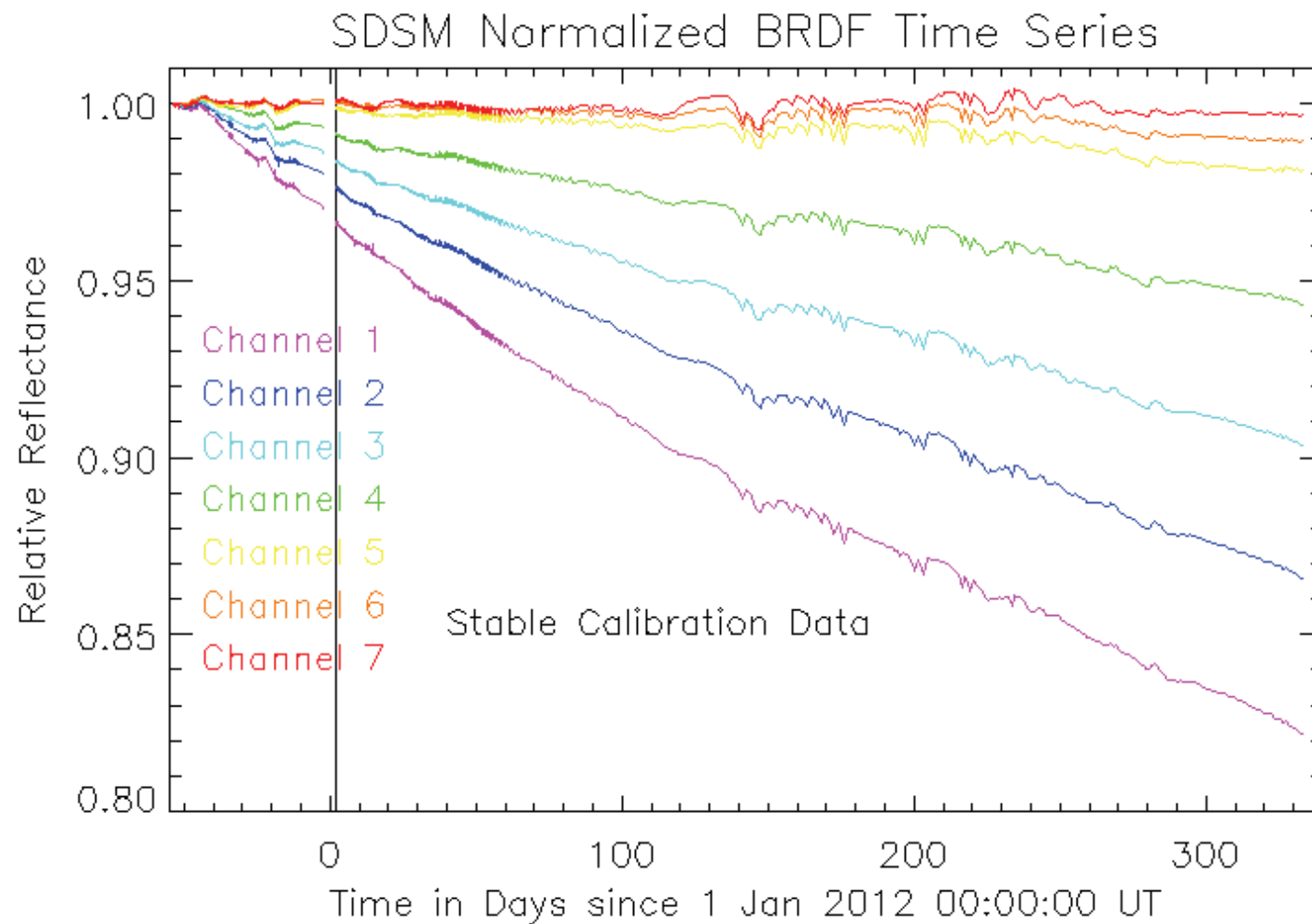
Concerns:

- NIR Degradation Anomaly for bands M5-M7
- BRDF Corrections for bands M1-M3
- Normalization of F-factor on January 2, at start of stable operations

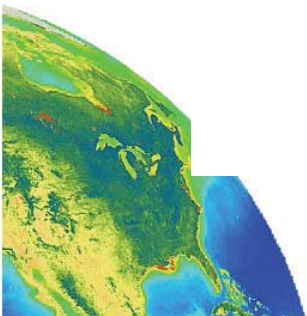
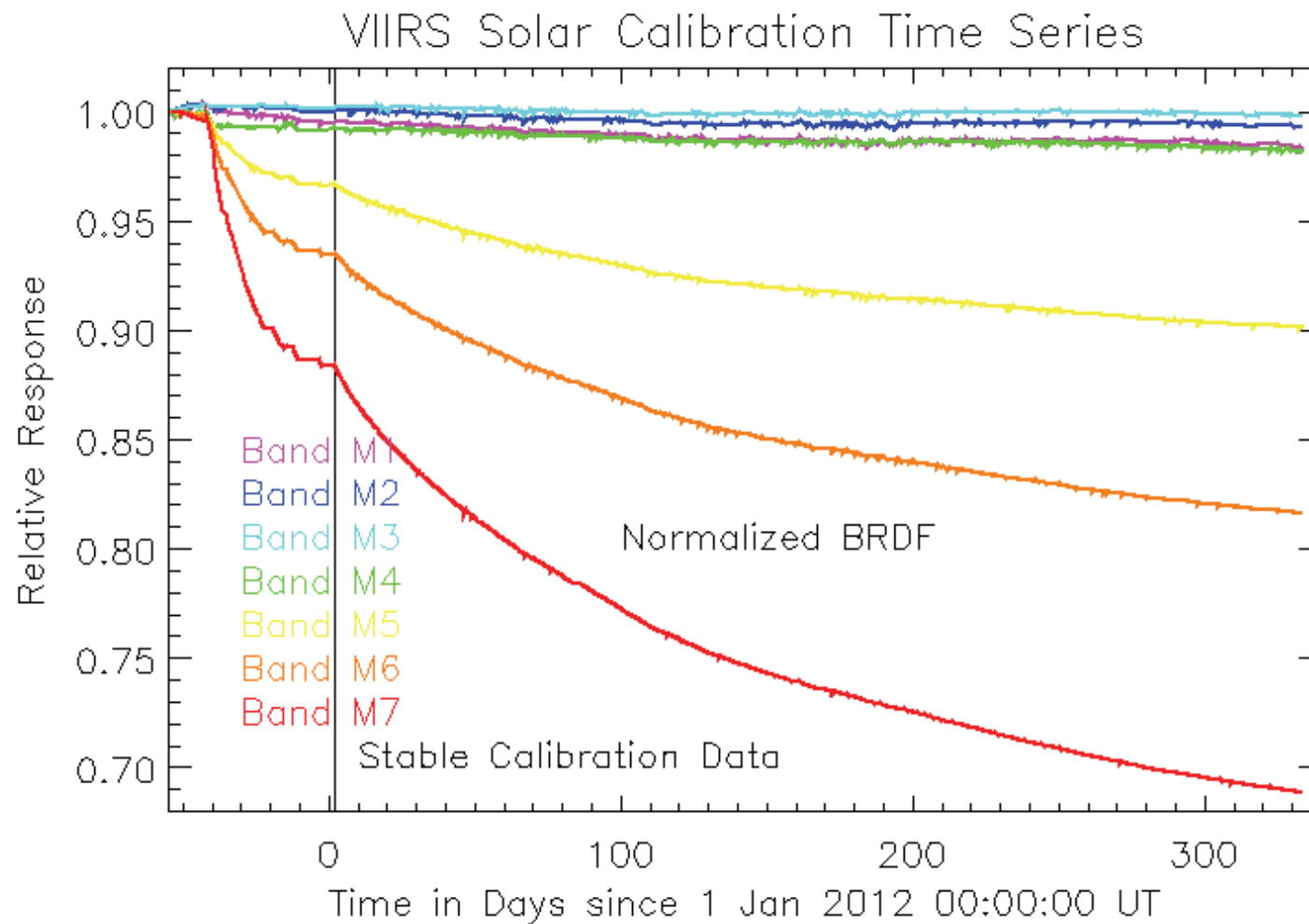
The following plots show the High Gain, Mirror Side 0 data.



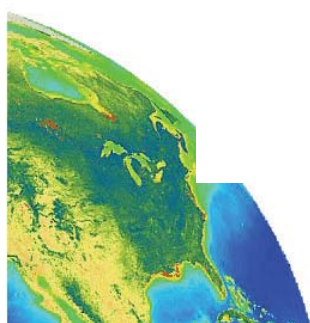
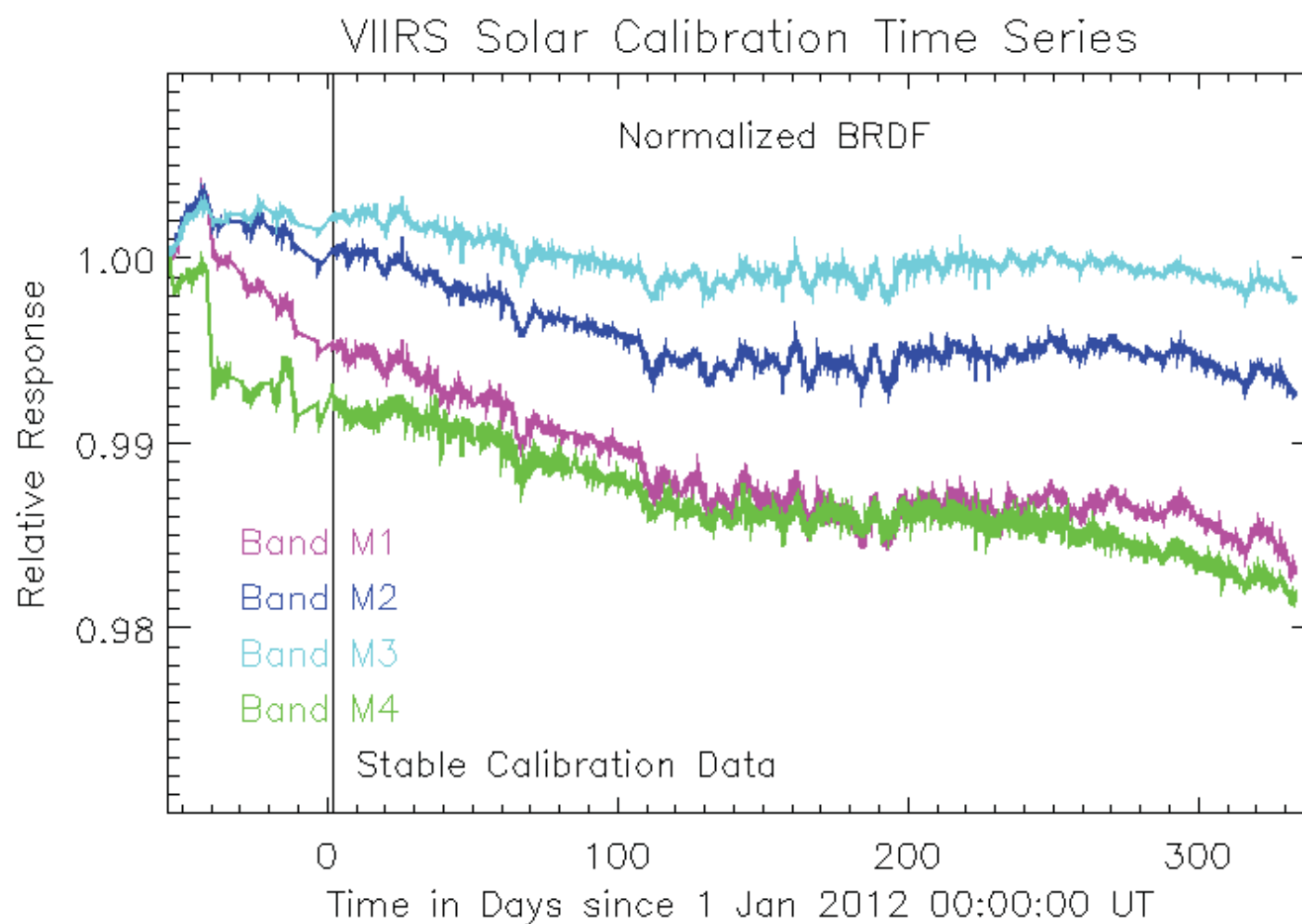
SDSM Time Series



Solar Time Series



Solar Time Series



Solar / Lunar Cal Comparison

Comparison methodology:

- Lunar and solar observations are at the same AOI on the half-angle mirror
- Determine F-factor at time of 1st lunar calibration
- Use lunar trend for each band to predict F-factor at the of subsequent calibrations
- Comparison of predicted lunar-derived F-factors with solar-derived F-factors

Observations:

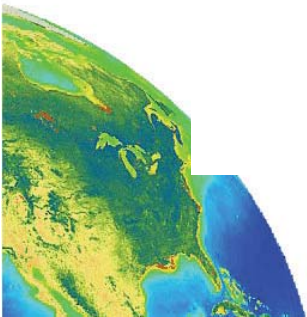
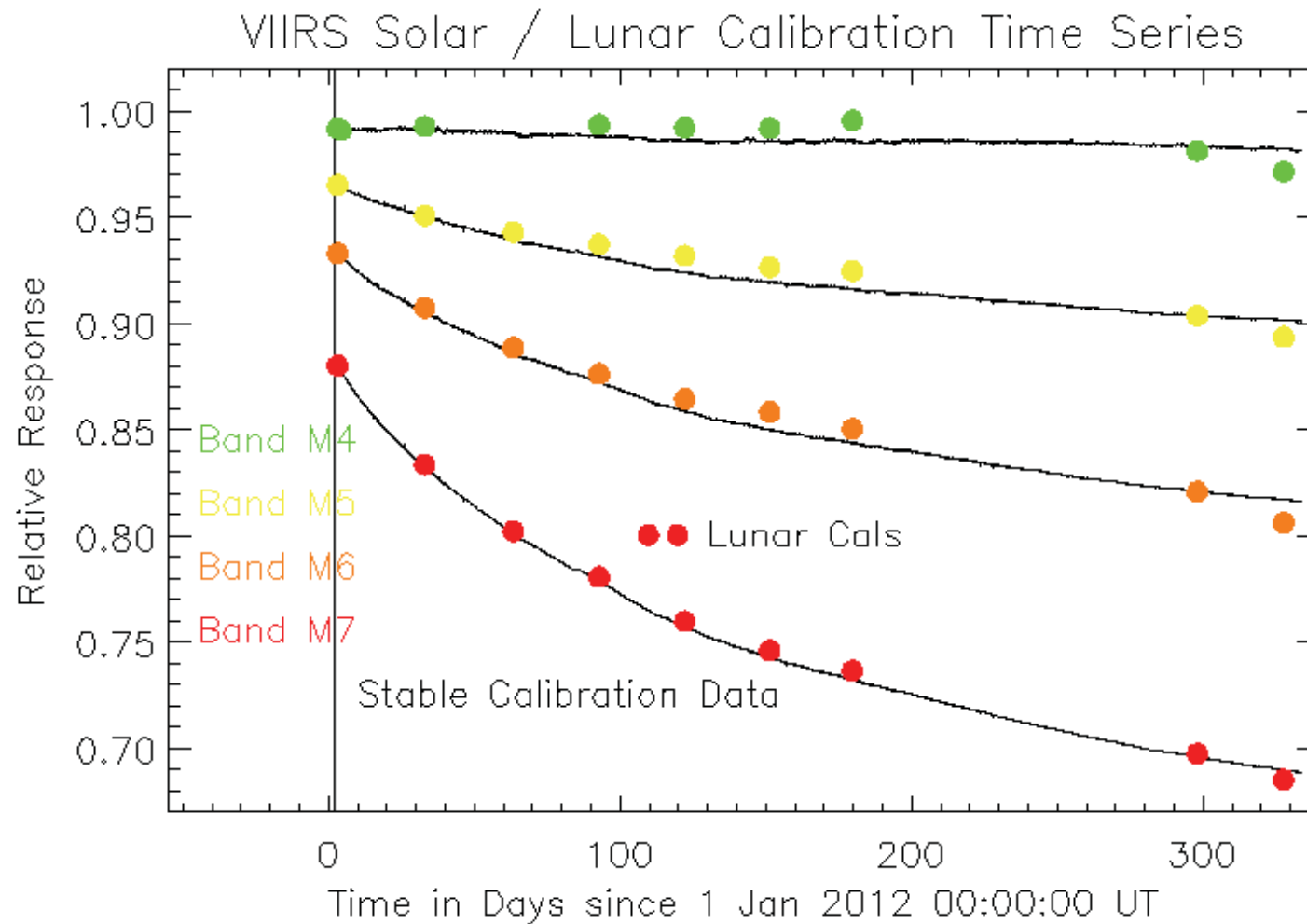
- Lunar trends imply a BRDF overcorrection which decreases with wavelength

Concerns:

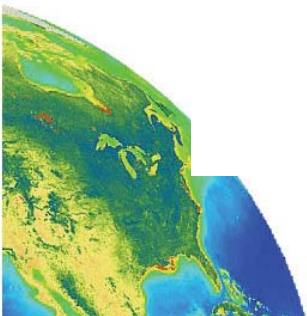
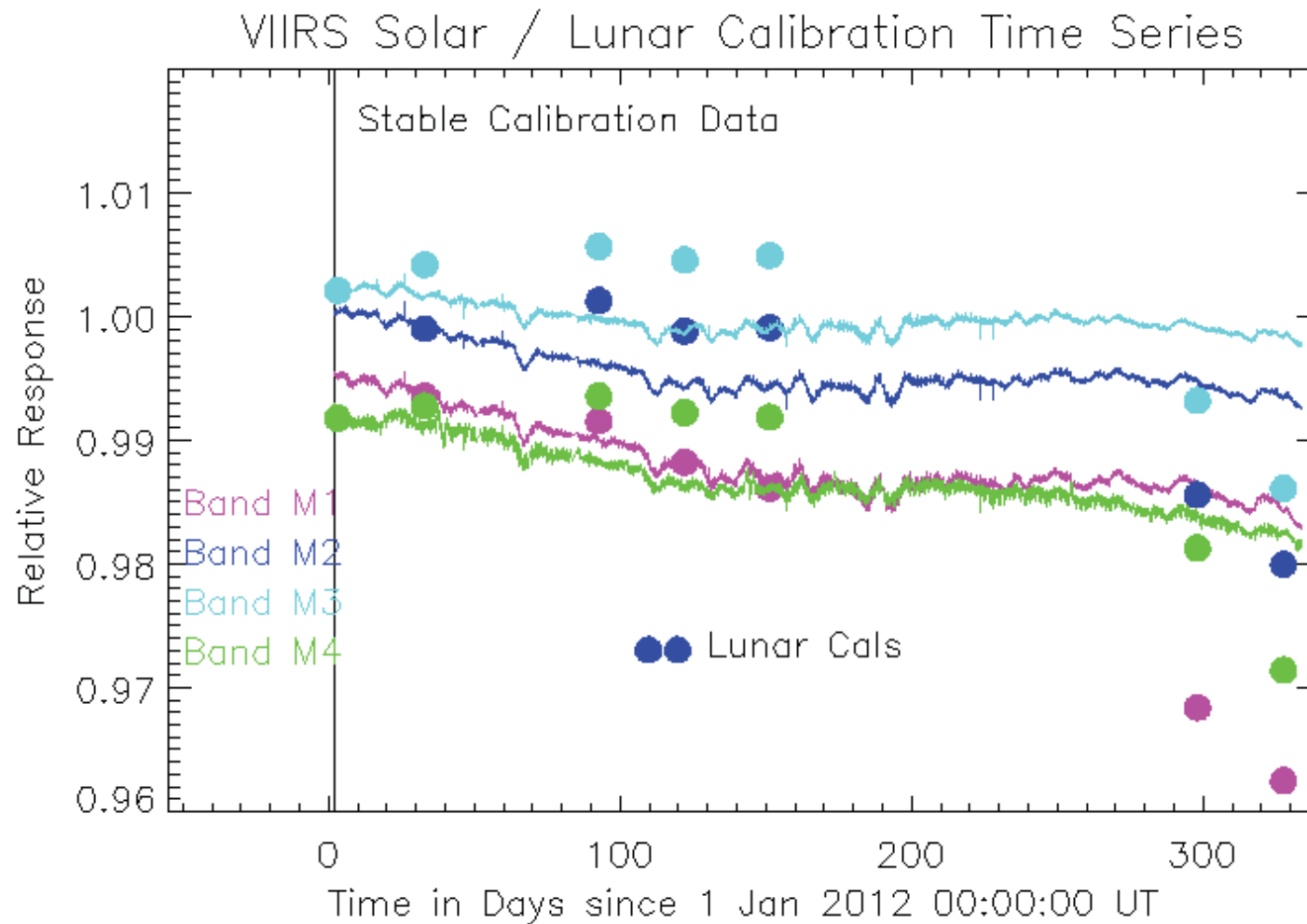
- Observational scatter in the lunar calibrations – at least a year of observations is required to assess the size of the scatter.
- Alternative F-factors are just now becoming practical



Solar / Lunar Comparison



Solar / Lunar Comparison



Conclusions:

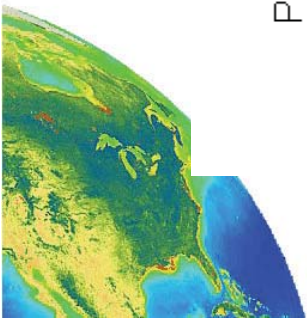
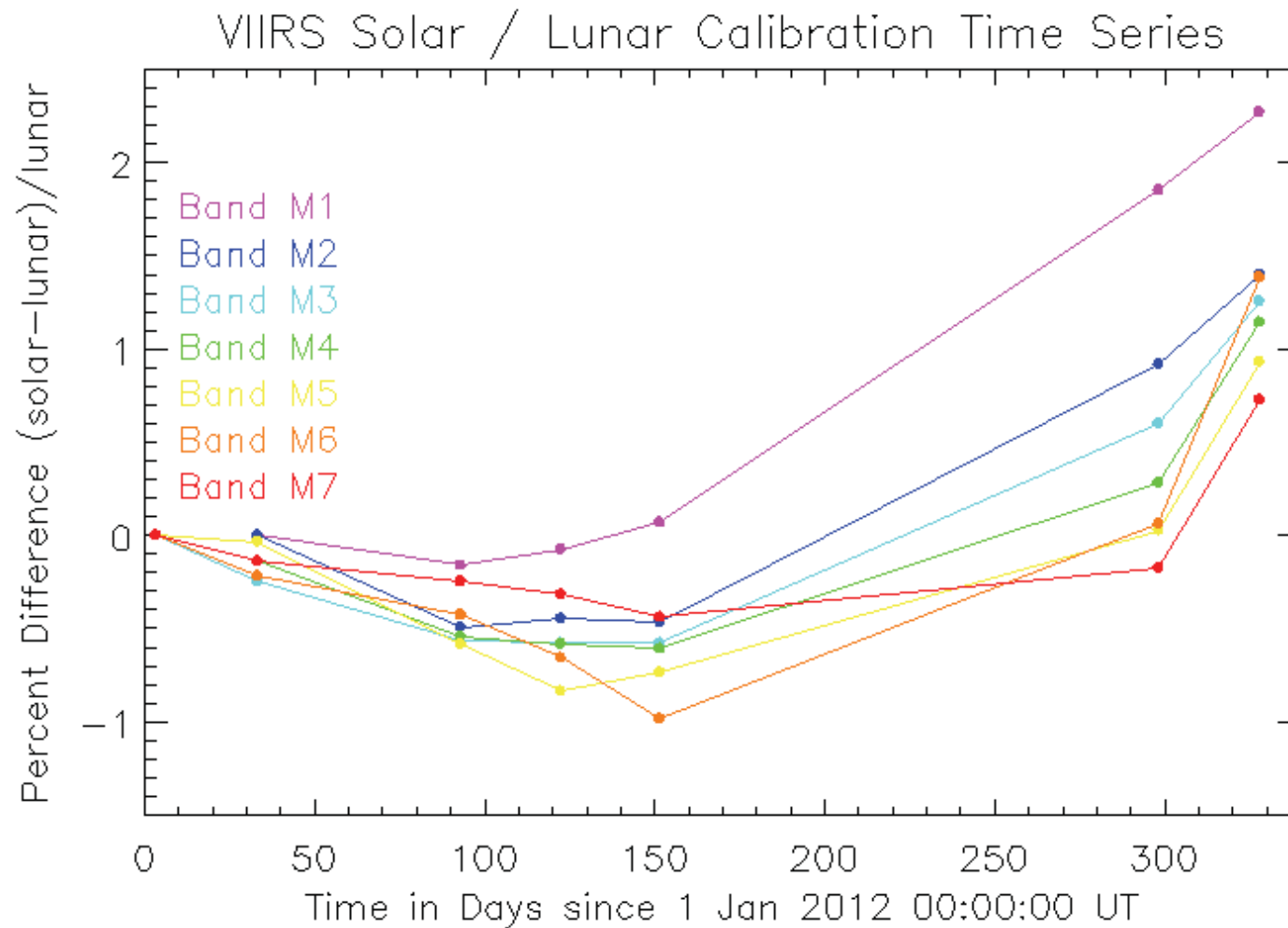
- Ocean color requires relative accuracy better than 0.5% (goal for future sensors: 0.2%)
- This goal requires accuracy focused approach for
 - 1) sensor design and specifications
 - 2) prelaunch sensor characterization
 - 3) on-orbit monitoring
- NASA OBPG believes lunar measurements are most accurate for long term trending (depends on sensor design)
- In the past, each sensor had its own issues with regard to calibration/characterization, I expect that to continue for future sensors



Backup slides



Solar / Lunar Comparison



2. Sensor requirements: Summary

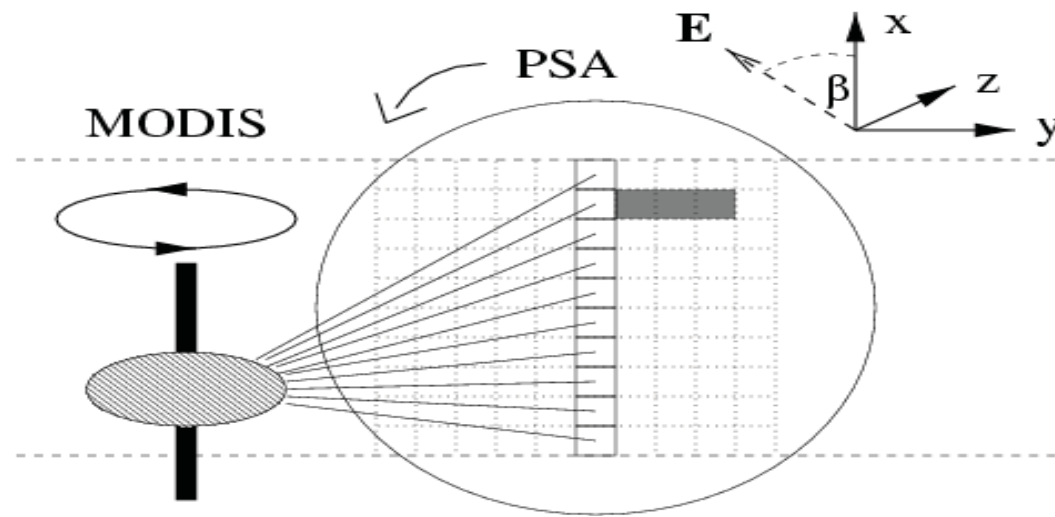
Sensor requirements should

- 1) ensure quality of data product
- 2) be achievable at reasonable cost
- 3) testable



MODIS Polarization Characterization: Setup documentation

Orientation of polarization angle relative to MODIS leaving
Polarization Source Assembly (PSA) not documented by Raytheon

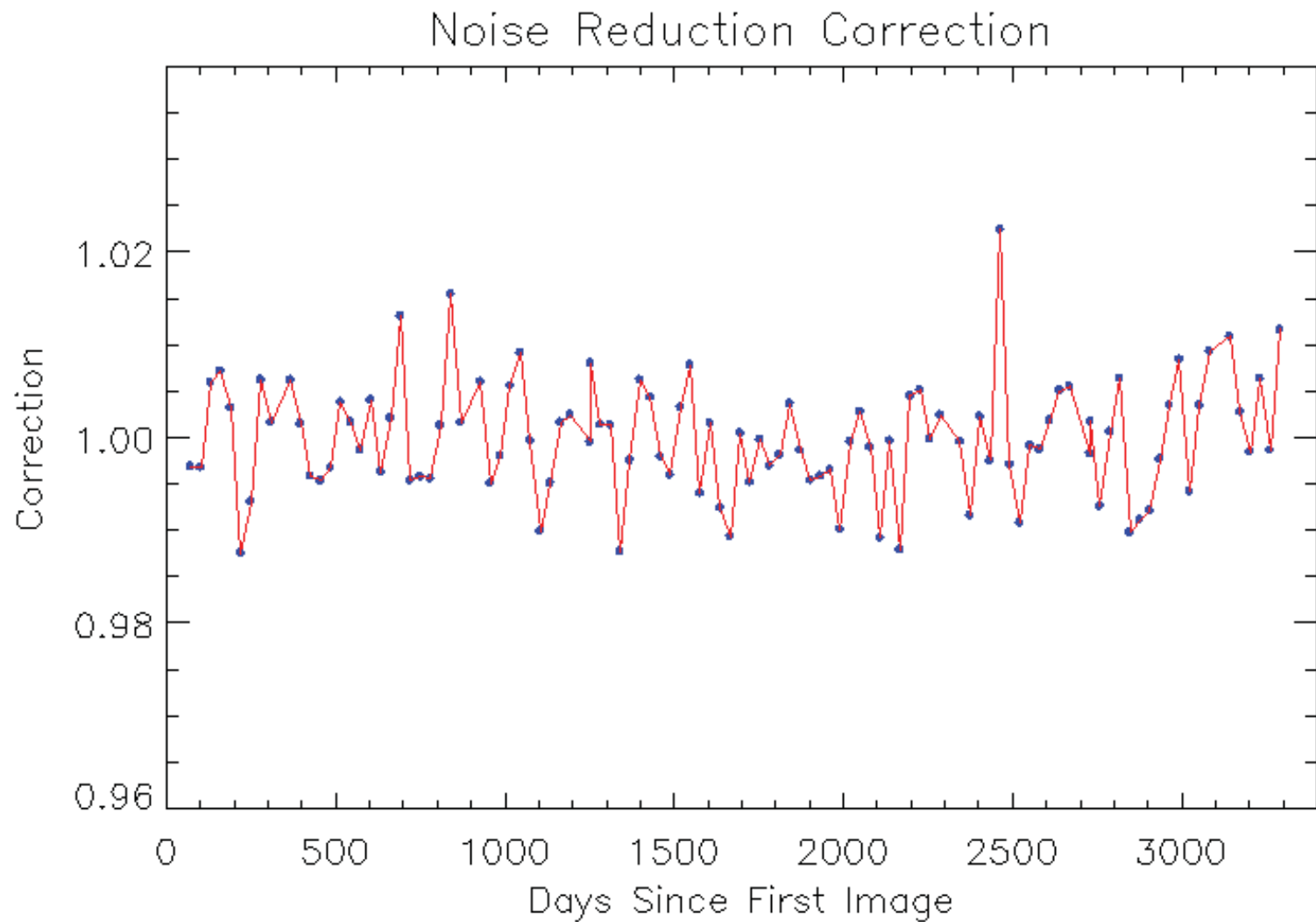


Setup reconstructed with help of E. Waluschka



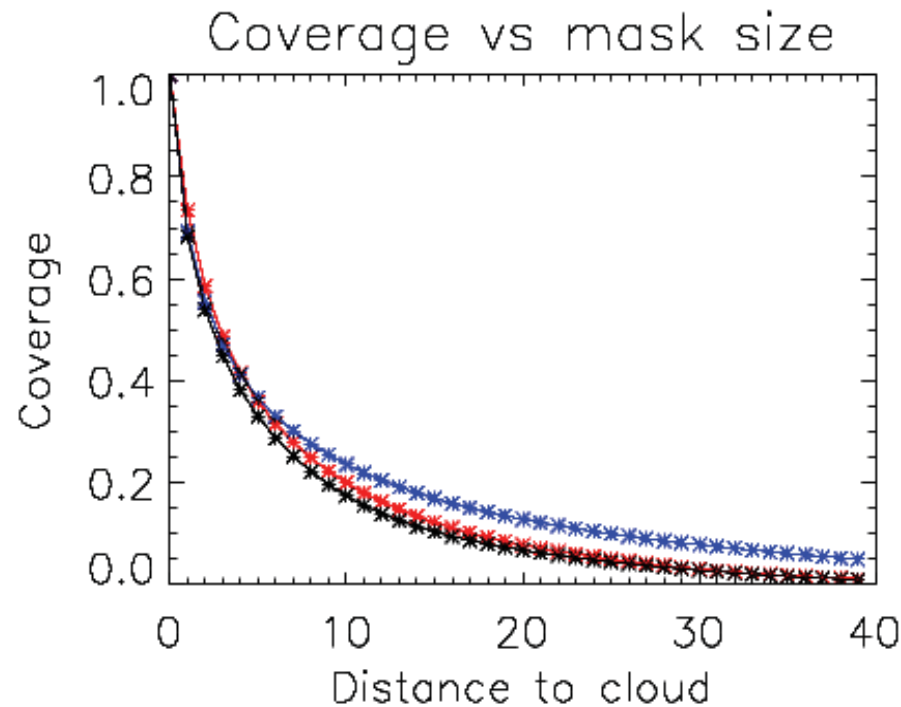
Fig. from Meister et al., 2005, Applied Optics⁵⁵

Band correlated noise:



Sensor requirements not strict enough: VIIRS

- Straylight masking influences global coverage
- Plot below shows reduction in coverage for masks around clouds for the 3 MODIS Aqua granules
- More straylight \Rightarrow larger mask \Rightarrow less coverage

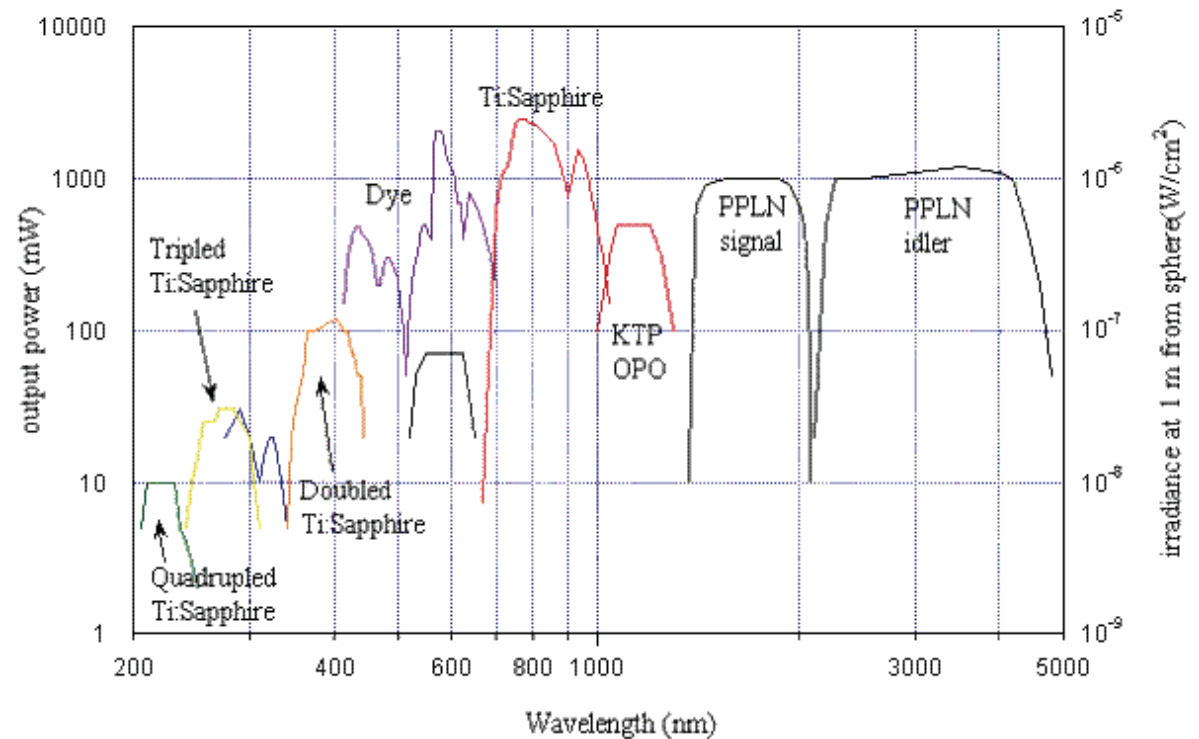
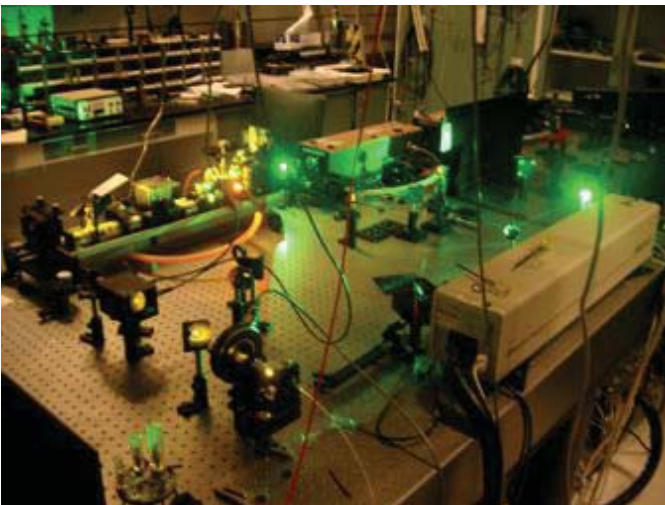


Relative Spectral Response:

- SeaWiFS characterization: mixture of piece-part and system level characterization
- MODIS: system level characterization (double monochromator)
- VIIRS: system level characterization (double monochromator and laser)
- If well characterized, OOB is manageable



VIIRS Relative Spectral Response:

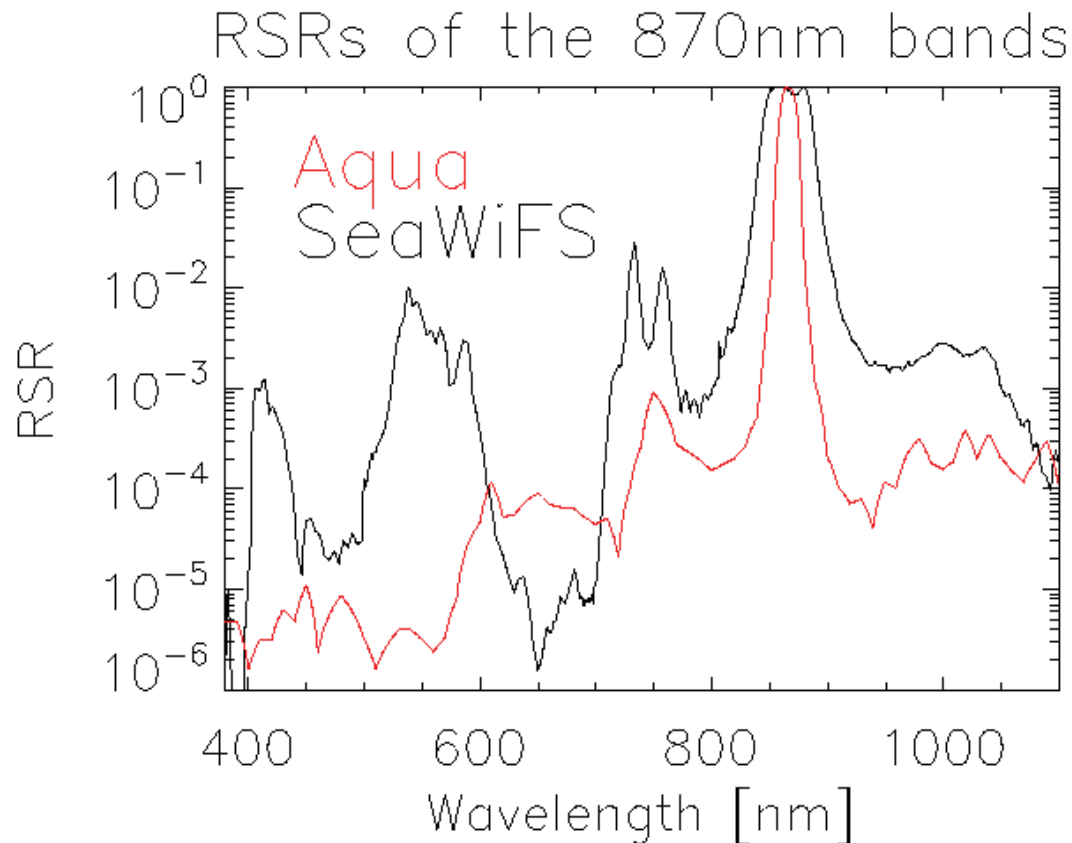


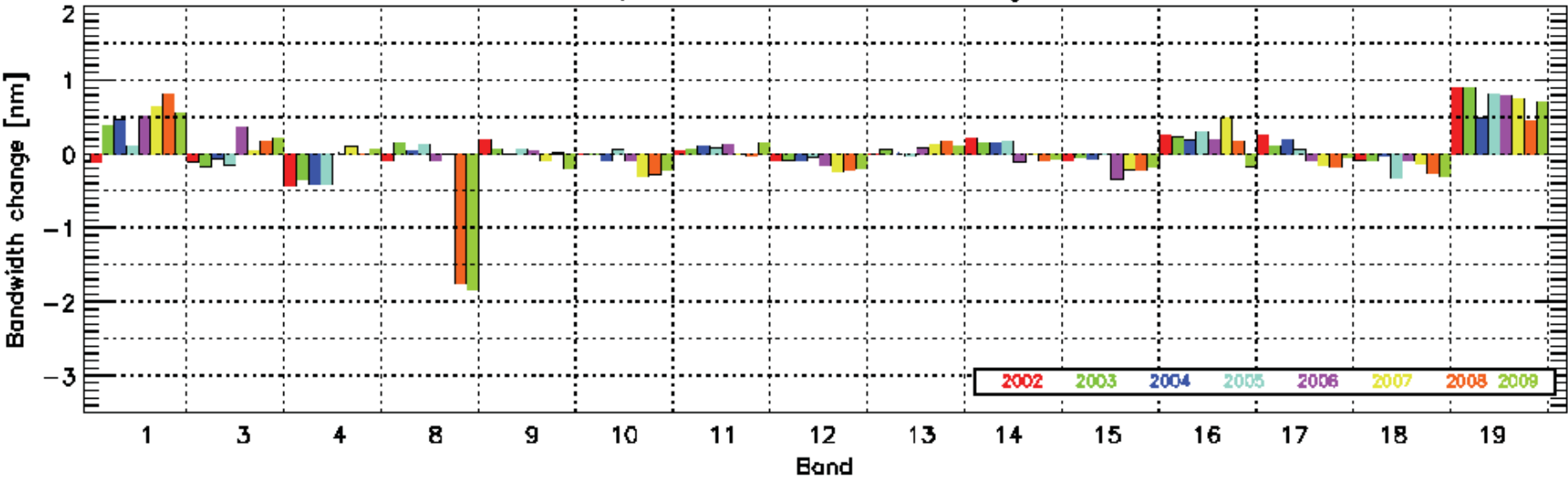
- Advantages: bright source, well calibrated
- Disadvantage: not continuous ($\Delta\lambda=0.1\text{nm}$), flood illumination (crosstalk)



SeaWiFS RSR OOB for 870nm

- SeaWiFS spec: ratio out-of-band RSR to in-band RSR up to 5%
- Actual band 8 value : 3.7%





Oversampling Correction

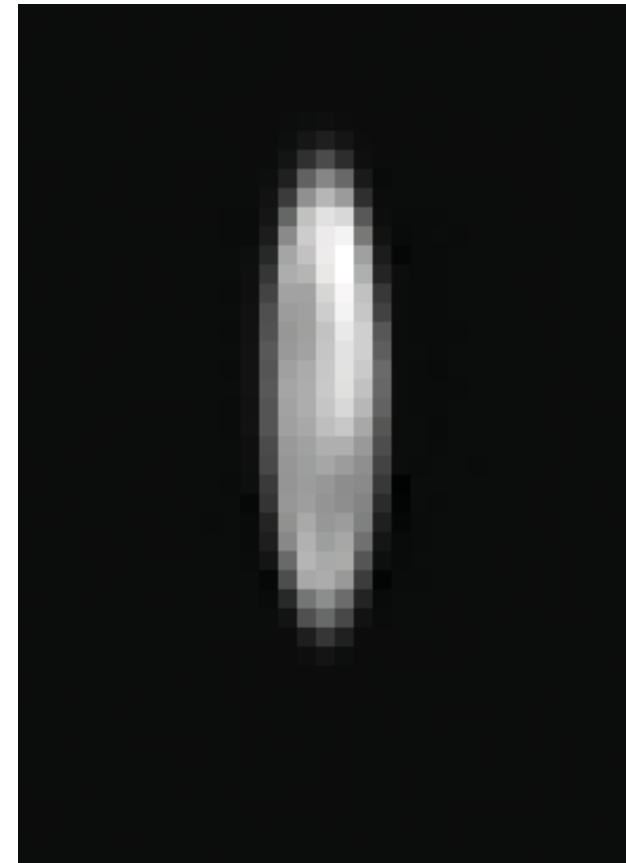
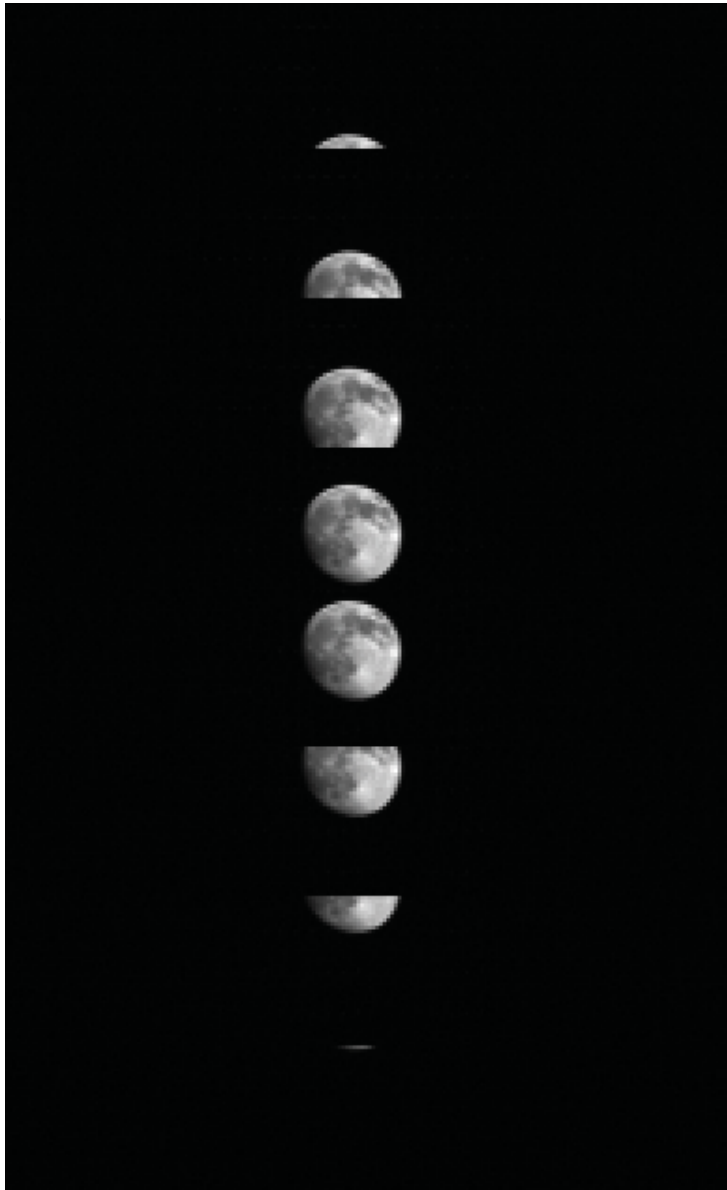
$$f(t, \alpha, \gamma) = \frac{1}{Y_{Moon}(\alpha, \gamma)} \arctan\left(\frac{D_{Moon}}{R_{Inst-Moon}(t)}\right)$$

- Y_{Moon} \equiv angular size of Moon in image
- D_{moon} \equiv diameter of Moon = 3476.4 km
- $R_{Inst-Moon}$ \equiv Instrument-Moon distance
- t \equiv time of observation
- α \equiv phase angle
- γ \equiv track angle



Lunar images may be oversampled:

MODIS band 1:
(image from
presentation
by J. Butler)



Sensor calibration: MODIS

- MODIS optics based on an (unprotected) rotating mirror
- Scan angle dependent degradation adds complexity to calibration approach

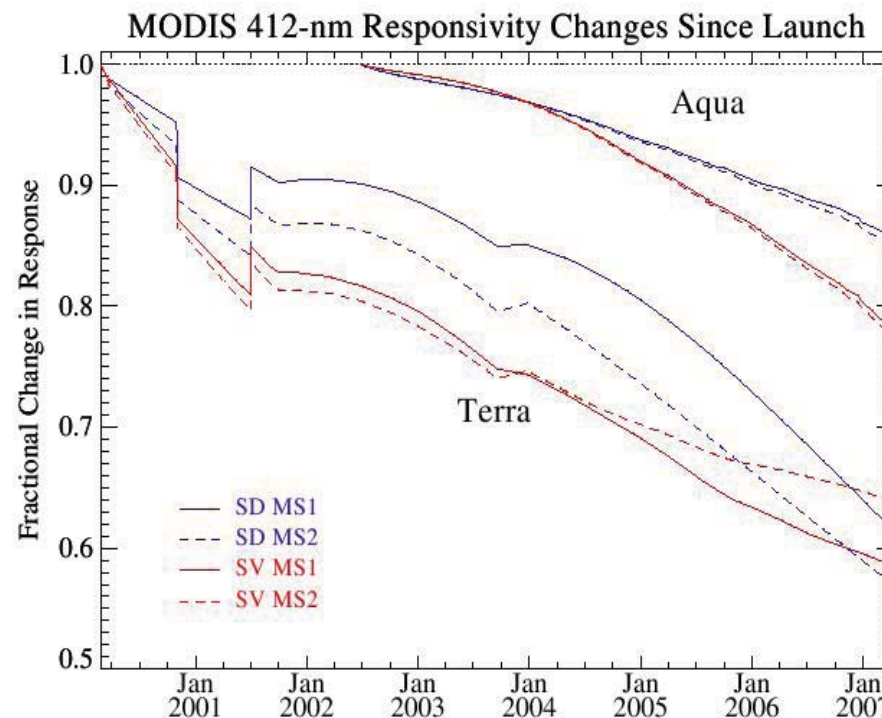
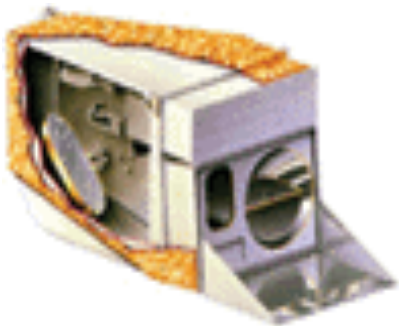
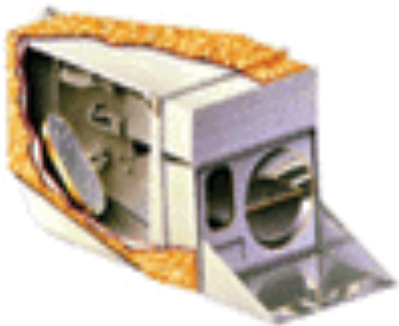


Fig. from
Franz et al.,
2008, Applied
Optics

Sensor calibration: MODIS

- MODIS uses two calibration sources: solar diffuser (SD) and moon (through space view (SV) port)
- Interpolation over $\Delta\text{AOI}=40^\circ$ and 10% gain change problematic, extrapolation even more

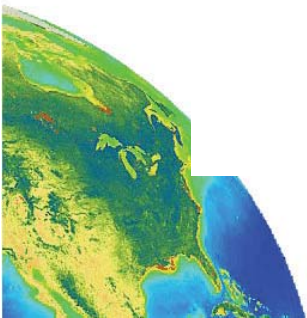
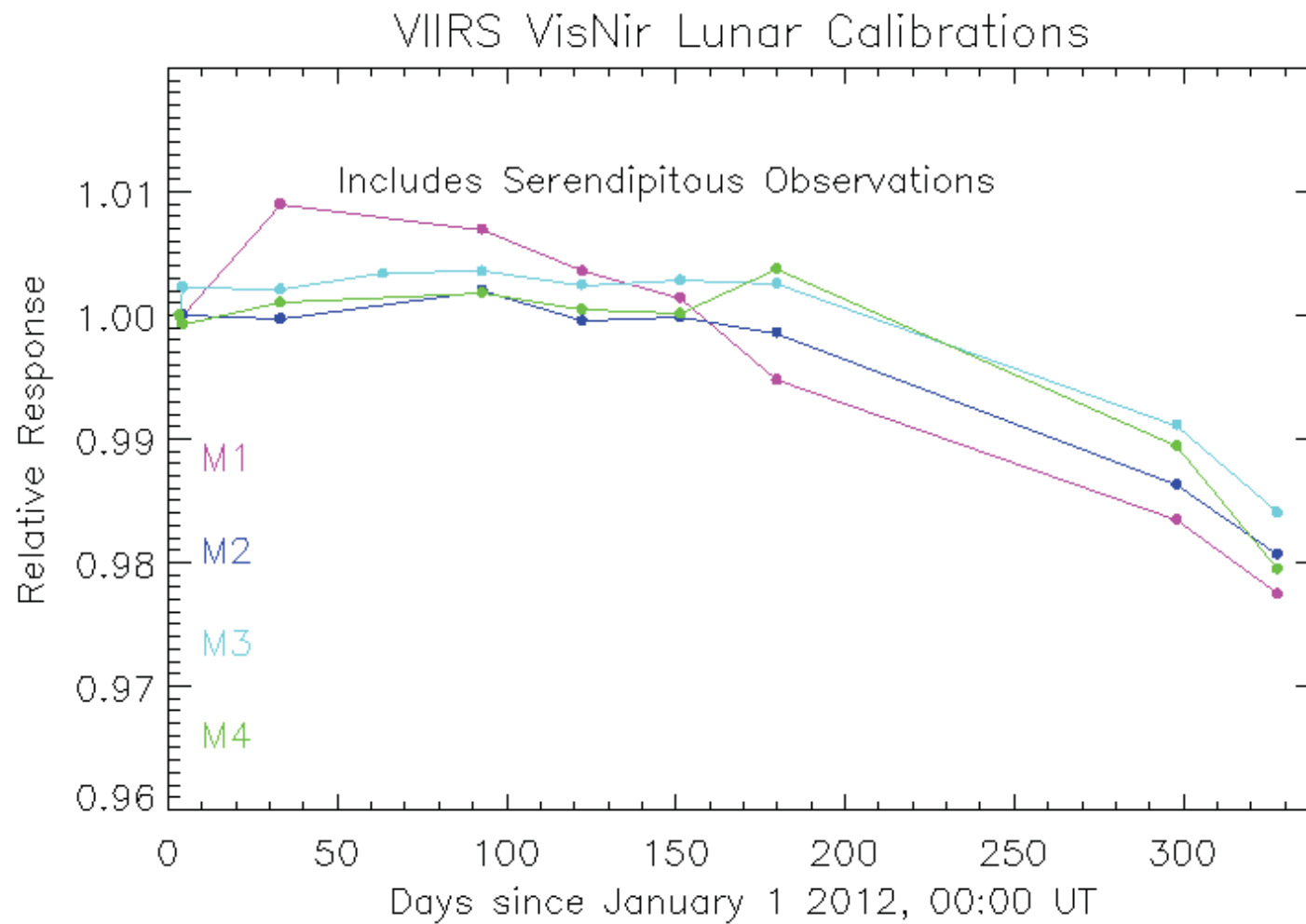


	Start	SV	Nadir	SD	End
Scan Pixel	1	23	677.5	979	1354
Scan Angle	-55.0	-53.2	0.0	24.5	55.00
Mirror AOI	10.5°	11.4°	38.0°	50.3°	65.5°

Table from Franz et al., 2008, Applied Optics



Lunar Time Series



Lunar Calibrations

Scheduled / Serendipitous Calibrations

- Moon below horizon for 3 months during the year

Lunar residuals from the USGS ROLO Photometric Model of the Moon

Comparison of Solar / Lunar Calibrations

- Same Angle of Incidence on Half-Angle Mirror

Alternate derivation of F-factor from lunar calibration time series

- Compensates for uncertainties in diffuser BRDF correction



Solar Calibrations

SDSM time series (H-factor): BRDF change:

Solar Diffuser time series (F-factor)

BRDF-corrected F-factor:



1. Ocean color requirements

OBPG produces different levels of data products, starting from level 0 (uncalibrated DN):

- 1) Level 1: calibrated radiances
- 2) Level 2: ocean color products (snapshot, no spatial averaging)
- 3) Level 3: ocean color products averaged over time and space (8-day, monthly, etc.)

